

ECBC-TR-

**TEST RESULTS OF PHASE 2 LEVEL B SUITS TO  
CHALLENGE BY CHEMICAL AND BIOLOGICAL  
WARFARE AGENTS AND SIMULANTS:  
SUMMARY REPORT**

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February 2001

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<b>REPORT DOCUMENTATION PAGE</b>			<i>Form Approved OMB No. 0704-0188</i>
Public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302, and to the Office of Management and Budget, Paperwork Reduction Project (0704-0188), Washington, DC 20503.			
1. AGENCY USE ONLY (Leave Blank)	2. REPORT DATE February 2001	3. REPORT TYPE AND DATES COVERED <b>Final; 99 Jan – 99 Sep</b>	
4. TITLE AND SUBTITLE <b>Test Results of Phase 2 Level B Suits to Challenge by Chemical and Biological Warfare Agents and Simulants: Summary report</b>			5. FUNDING NUMBERS <b>None</b>
6. AUTHOR(S) <b>Lindsay, Robert S. Pappas, Alex G.</b>			
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) <b>DIR, ECBC, ATTN: AMSSB-RRT-CE, APG, MD 21010-5424</b>			8. PERFORMING ORGANIZATION REPORT NUMBER <b>ECBC-TR-</b>
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES) <b>CDR, SBCCOM, ATTN: AMSSB-ODP, APG, MD 21010-5424</b>			10. SPONSORING/MONITORING AGENCY REPORT NUMBER
11. SUPPLEMENTARY NOTES			
12a. DISTRIBUTION/AVAILABILITY STATEMENT <b>Approved for public release; distribution is unlimited.</b>			12b. DISTRIBUTION CODE
13. ABSTRACT (Maximum 200 words) <b>Swatches from seven commercially available Level B protective suits were challenged with liquid droplets of Sarin (GB) and mustard (HD) using modifications of the static diffusion procedure described in TOP 8-2-501. The cumulative mass of each agent that permeated each swatch was determined over time, and the results for all swatches were used to determine a weighted-average cumulative mass for each suit. From these data, a breakthrough time was calculated for each suit for the purposes of comparison. In addition, intact suits were challenged with corn-oil aerosol to simulate a biological or chemical aerosol. Protection factors were determined for each suit.</b>			
14. SUBJECT TERMS <b>HD      Swatch testing      Permeation testing GB      Aerosol Testing      Chemical protective suits</b>			15. NUMBER OF PAGES <b>83</b>
			16. PRICE CODE
17. SECURITY CLASSIFICATION OF REPORT <b>UNCLASSIFIED</b>	18. SECURITY CLASSIFICATION OF THIS PAGE <b>UNCLASSIFIED</b>	19. SECURITY CLASSIFICATION OF ABSTRACT <b>UNCLASSIFIED</b>	20. LIMITATION OF ABSTRACT <b>UL</b>

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## **EXECUTIVE SUMMARY**

As part of the Domestic Preparedness Program, seven Occupational Safety and Health Level B\* suit designs were tested to assess their capability to protect in a chemical warfare (CW) agent or biological agent environment. Swatches of material from each suit design were tested for resistance to permeation for Sarin (GB) and mustard (HD). From this data, the authors calculated the estimated time it would take to permeate the suit with sufficient agent to cause physiological effects in a person wearing the suit. Each suit design was also tested for its protection factor in an aerosol environment (aerosolized corn oil, which may be representative of a chemical or biological agent, was used). Protection factor is defined as the ratio between the challenge concentration outside the suit and the measured concentration inside the suit. The tests are described, and the calculated breakthrough times and overall protection factors are presented.

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\* Level B protection consists of chemical-resistant clothing (overalls and long-sleeved jacket; hooded one or two piece chemical splash suit; disposable chemical-resistant one-piece suit), inner and outer gloves, chemical-resistant safety boots and hard hat with pressure-demand full-facepiece SCBA or pressure-demand supplied-air respirator with escape SCBA. Level B, rather than Level A, protection is used when a high level of respiratory protection is required but less skin protection is needed.

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## **PREFACE**

The work described in this report was authorized under the Expert Assistance (Equipment Test) Program for the U.S. Army Soldier and Biological Chemical Command (SBCCOM) Program Director for Domestic Preparedness.

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### **Acknowledgments**

The author acknowledge John Baranoski and Janice Hannigan for conducting the tests upon which this report is based; and Frank DiPietro for managing the equipment acquisition and test scheduling necessary to accomplish the testing in a timely manner.

The author also acknowledges the technical contributions of the Expert Review Panel for Personal Protective Equipment (PPE) Testing as listed below:

Dr. Jimmy Perkins, University of Texas School of Public Health, San Antonio, TX.  
Dr. Annetta Watson, Life Sciences Division, Oak Ridge National Laboratory, Oak Ridge, TN  
Dr. Ted Zellers, University of Michigan School of Public Health, Ann Arbor, MI  
Leo F. Saubier, Battelle Memorial Institute, Edgewood, MD

The panel reviewed and commented on the test procedures, instrumentation, data analysis and presentation. Their guidance was a valuable element in the development of clear and adequate descriptions of the concepts and procedures used in these tests.

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# TEST RESULTS OF PHASE 2 LEVEL B SUITS TO CHALLENGE BY CHEMICAL AND BIOLOGICAL WARFARE AGENTS AND SIMULANTS: SUMMARY REPORT

## 1. INTRODUCTION

In 1996, Congress passed Public Law 104-201 (Defense Against Weapons of Mass Destruction Act of 1996), directing the Department of Defense (DoD) to assist other federal, state, and local agencies in enhancing preparedness for terrorist attacks using weapons of mass destruction. The DoD responded by forming the Domestic Preparedness Program that same year. One of the objectives of the Domestic Preparedness Program is to enhance emergency and hazardous material response to nuclear, biological and chemical (NBC) terrorism incidents. As part of an effective response, people who are responding to an incident will use personal protective equipment to protect them from exposure to chemical agents or biological agents. The specific personal protective equipment (PPE) that will be used depends upon the situation that they encounter and what they have on hand. In some cases, Level B protective suits may be required to enter a contaminated or potentially contaminated area. Level B suits are chemical-resistant clothing that protect the wearer from liquid chemicals. Air is supplied by a pressure-demand full-facepiece self-contained breathing apparatus (SCBA) or pressure-demand supplied-air respirator with escape SCBA.

## 2. OBJECTIVES

This study evaluates seven different common and commercially-available Level B suits. These seven different suits met the Occupational Safety and Health Administration (OSHA) description of Level B as defined in 29 Code of Federal Regulations (CFR) 1910.120, Appendix B. These suits were evaluated to assess how well they resist vapor permeation from liquid contamination<sup>1</sup> by chemical agents Sarin (GB) and mustard (HD) and droplet penetration by a corn-oil aerosol used to simulate biological or chemical particulates from 0.4 to 5 µm in diameter (military standard for the possible threat). This information is intended for emergency responders as an aid in evaluating Level B suits when they choose to include military chemical and biological agent protection as a criterion. The information supplements data and information provided by the suits' manufacturers. The suits are tested in new, as-received condition. The effects of aging, temperature extremes, laundering, and other factors are beyond the intended scope of this test program. These tests are conducted to assess percutaneous protection<sup>2</sup> only.

## 3. TESTING AND DATA ANALYSIS

### 3.1 Testing Overview.

The Level B suits that are tested in this test program are listed in Appendix A. Tests include the measurement of permeation of both GB and HD through material swatches.

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<sup>1</sup> Throughout this report the term permeation is used even though for some of the tests the precise mechanism of agent transfer is not determined and penetration is likely to be involved also.

<sup>2</sup> Inhalation and ocular protection are typically provided by the use of a SCBA or air-supplied respirator that covers the eyes, nose and mouth.

Tests are also conducted to measure the total aerosol leakage into the suits when worn as part of a complete PPE system.

3.2        Liquid Challenge/Vapor Permeation Testing (Agent Swatch Testing)

3.2.1      Liquid Challenge/Vapor Permeation Testing Procedures.

This testing is conducted to measure the actual permeation of chemical agents GB and HD through suit swatches over a 24-hr period. The test is intended to assess how well the suit materials and seams resist agent permeation. The amount of agent applied and duration of exposure do not represent any particular threat that responders may encounter, but they do serve as a common point of reference for all test results.

The test methodology was taken from TOP 8-2-501<sup>3</sup> and is described in Appendix B. Three swatches are taken from each of six different areas of the suit – 18 total swatches per suit design for GB and 18 more for HD. Swatches are taken from silicone rubber (M45 mask formulation) slabs<sup>4</sup>. For each test six swatches taken from a suit and one silicone swatch are placed in test cells; one swatch per test cell. Laboratory personnel apply a predetermined liquid agent challenge ( $10 \text{ g/m}^2$ ) to the top surface of each swatch. Agent droplets are applied to the surface of the first swatch at time zero. Agent is then applied to the surface of each succeeding swatch at 3-min intervals. The upper chamber of each test cell is sealed. A 1.0 L/min flow of air, from the test cabinet, is maintained in the lower test cell chamber beneath each swatch.

During the 24-hr test period, gas samples are taken on a sequential basis by a laboratory MINICAMS™ (OI Analytical, CMS Field Products Group, Birmingham, AL) with stream selection system (a miniaturized gas chromatograph with flame photometric detector and sampling system) from the airstream beneath each swatch. Gas sampling by the MINICAMS™ begins for the first swatch approximately 3 min following agent application. Subsequent 3-min cycles of the MINICAMS™ are composed of 2 min of desorption of collected agent vapor from the pre-concentrator tube (PCT) onto the GC column followed by 1 min of gas sampling (collection of agent vapor in the PCT). Sampling is done sequentially through six swatches (three from one sampling area followed by three from a second sampling area), the silicone swatch, and then three blank gas samples are taken from the test chamber to purge the sampling line before repeating the sampling sequence. The six swatches, the indicator swatch, and three blanks are all sampled for the first time within the first 30 min of the test. Then the sampling sequence begins anew.

The MINICAMS™ first determines the amount of agent vapor in each gas sample. Using this result, the amount (ng) of agent vapor present in the airstream that passes beneath the swatch over the time from the previous gas sample to the current gas sample is determined by the

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<sup>3</sup> Test Operations Procedure (TOP) 8-2-501, Permeation and Penetration of Air-Permeable, Semipermeable and Impermeable Materials with Chemical Agents or Simulants (Swatch Testing). U.S. Army Dugway Proving Ground, UT. 3 March 1997, UNCLASSIFIED Report (AD A322329).

<sup>4</sup> Originally, it was intended to use silicone swatches as references or controls, but it was soon found that permeation through the silicone varies too widely for it to be used for that purpose. Silicone swatches were used anyway, because they serve as a reliable source of agent vapor to assure the tester that the MINICAMS™ is responding properly during tests when little or no agent permeates the actual test swatches.

MINICAMS™ permeation software. This amount of agent vapor is presumed to be the amount of agent vapor that has permeated the swatch over that time interval. Given the area of the test swatch, the MINICAMS™ permeation software determines the  $M_f$  at each elapsed time for each swatch. Over the 24-hr test period, a series of  $M_f$  values is calculated for each swatch. The cumulative mass of agent permeating the swatch per unit area at any elapsed time during the 24-hr test is defined as  $M_f$ .

### 3.2.2 Liquid Challenge/Vapor Permeation Testing Analysis.

Each suit yielded  $M_f$  data for 18 swatches for each of the two agents over the 24-hr test period. The  $M_f$  data are taken for each of the three swatches from one sampling area tested with one of the agents. For this report, the average (of three swatches) cumulative permeation ( $M_f$ ) for each suit area (for example, gloves) is calculated. This average is then presented, at each of the reported elapsed times, as representative of the suit's permeation resistance at that sampling area. The reported elapsed time for each sampling area is the sum of the elapsed times for the three swatches divided by three. For each suit tested, swatches were taken from a single suit.

To estimate  $M_f$  at each elapsed time for a suit, the simplifying assumption is that the exposure is uniform over the entire suit. This permits the use of the weighting factor scheme developed by Belmonte<sup>5</sup> to determine the weighted average  $M_f$  over the entire suit at each average elapsed time. The average elapsed time is the sum of the reported elapsed times for all the sampling areas divided by the number of sampling areas. The weighting factors shown in Table 1 were assigned roughly on the basis of surface area assigning a minimum assigned value of 5%. Swatches were not necessarily taken from exactly the same locations for all suits because the suit configurations differed. Note that not all suits have the same components. The weighted average  $M_f$  at any average elapsed time is calculated using an equation similar to the following (using the Kappler CPF1 weighting factors in Table 1 for this example):

$$\text{Weighted average } M_f = 0.5(\text{suit material } M_f) + 0.2(\text{suit seam } M_f) + 0.1(\text{boot material } M_f) + 0.05(\text{boot seam } M_f) + 0.1(\text{hood material } M_f) + 0.05(\text{zipper/material interface } M_f)$$

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<sup>5</sup> Belmonte, R.B., *Test Results of Level A Suits to Challenge by Chemical and Biological Warfare Agents and Simulants: Summary Report*, ERDEC-TR-513, U.S. Army Edgewood Research, Development and Engineering Center, Aberdeen Proving Ground, MD, August 1998, UNCLASSIFIED Report (AD A353013).

**Table 1. Weighting Factors For Each Sampling Area by Suit**

Suit Model	Weighting Factor, Percent, for Each Sampling Area								
	Suit Material	Crotch Area	Suit Seam	Glove Material	Boot Seam	Hood Seam	Boot Material	Hood Material	Zipper/Material Interface
TFR4 CB Protective Coverall (Tyvek F)	50	10	20	-	-	5	-	10	5
Kappler ProShield 3 Coverall	50	-	20	-	5	5	10	10	-
Kappler CPF1Coverall	50	-	20	-	5	-	10	10	5
Kappler CPF2 Coverall	50	-	20	-	5	-	10	10	5
Kappler CPF4 Coverall	50	-	20	-	5	-	10	10	5
Kappler Responder (41255-8A)	50	-	20	-	5	-	10	10	5
Kappler Level B CSM Responder (42489)	50	-	20	10	5	-	10	-	5

### 3.2.3

#### Relationship Between Liquid Challenge/Vapor Penetration Test Results and Skin Exposure.

The permeation test is designed to distinguish among these material swatches according to their permeation resistance to chemical agents. It is not intended to specifically replicate threat scenarios that may be encountered in actual use. As previously reported by Belmonte<sup>5</sup>, it is instructive to estimate the agent dosage ( $C_{t,skin}$ ) that would result from such a standard agent challenge as a relative indication of possible physiological effects. This is done by converting the weighted average  $M_f$ s to equivalent agent dosages. This relationship was developed by Fedele (written communication, Dr. P. Fedele, R&T Directorate, ERDEC, July 1997) and was reported by Belmonte<sup>5</sup>. For suit materials impermeable to airflow, the equation is:

$$\text{Agent Dosage (mg - min/m}^3) = \frac{M_f \text{ (ng/cm}^2\text{)}}{P_s \text{, Permeability of skin to agent vapor (cm/min)}}$$

where skin permeability ( $P_s$ ) is 2 cm/min for HD and 0.1 cm/min for GB. The agent dosage can then be compared to doses that are known to cause certain levels of toxicity. Skin permeability is assumed to be constant over all regions of the body.

## 3.2.4

Evaluation Criteria for Liquid Challenge/Vapor Permeation Test Results.

When analyzing the test results, it is useful to determine whether the data indicate that the Level B suit provided percutaneous (i.e., skin) protection over some period of time. Mustard vapor can produce erythema (reddening of the skin, certain body regions) at dosages of approximately 100 mg-min/m<sup>3</sup>, and can produce vesication (skin burns and blisters, certain body regions) at 200 mg-min/m<sup>3</sup>. Sarin vapor can produce incapacitation (twitching, convulsions or loss of consciousness) at unprotected, percutaneous dosages of approximately 8000 mg-min/m<sup>3</sup> and can be lethal at unprotected, percutaneous dosages of 15000 mg-min/m<sup>3</sup> where exposed persons are healthy, young, fit, and well-nourished males of approximately 70-kg mass. People who are smaller, less fit, etc., may exhibit adverse effects at lower doses ( $C_i t_{skin}$ ). The simplifying assumption was that the suit was exposed to a uniform liquid GB challenge over its entire surface, resulting in a uniform exposure of all body regions to GB vapor. Therefore, the amount of agent per unit area (weighted average  $M_f$ ) necessary to permeate the suit to produce a predetermined physiological effect was estimated by using each of the above dosages and the appropriate skin permeability ( $P_s$ ). These values are used in the graphs of weighted average  $M_f$  versus time given in Appendixes D through I and summarized in Table 2. The breakthrough dosages are assumed to be the HD dosage that produces erythema (100 mg-min/m<sup>3</sup>) and the GB dosage that produces incapacitation (8000 mg-min/m<sup>3</sup>). A breakthrough time is the time when the weighted average  $M_f$  equals the breakthrough  $M_f$  criterion.

**Table 2. Agent Breakthrough Criteria**

Agent	Breakthrough Dosage (mg-min/m <sup>3</sup> )	Physiological Effect	Skin Permeability ( $P_s$ ), (cm/min)	Breakthrough $M_f$ , (ng/cm <sup>2</sup> )
HD	100	Erythema	2	200
HD	200	Vesication	2	400
GB	8000	Incapacitation	0.1	800
GB	15000	Lethality	0.1	1500

## 3.3

System Test (Aerosol Simulant)

## 3.3.1

Aerosol Simulant Test Procedures.

The testing was conducted to determine leakage of a challenge corn-oil aerosol (physical simulant of a biological or chemical agent aerosol) into a suit ensemble while people were wearing ensembles of different sizes. Volunteers dressed in Level B suits with SCBA entered a chamber with aerosol simulant. Instrumentation measured any aerosol leakage (presumed to be penetration) into the suit through gaps between ensemble components. During the test, the people in the suits performed standardized movements. A brief description of the test and movements made by the people during the test are given in Appendix C. Seven different ensembles, listed in Appendix A, were tested. Eight suits of each design were worn by 12 volunteers on each of two days (not necessarily the same 12 on both days), for a total of 24 trials for each suit design. Thus not all of the volunteers or suit replicates were used in equal numbers of trials to accomplish the tests.

From this test a protection factor (PF) is derived. In simplest terms, PF is a measure of the challenge concentration outside the suit divided by the concentration inside the suit ensemble. For example, if the concentration of aerosol inside the suit ensemble is found to be 1/10th the value of the average concentration outside the suit ensemble, the PF is equal to 10.

### 3.3.2        Aerosol Simulant Analysis.

Samples of aerosol are taken continuously at the neck area and upper arm within the suit and their concentrations are measured by laser photometry, recorded in a computer file and displayed continuously on a computer monitor. These sampling locations were selected as being the most likely locations for aerosol leakage to occur. This is thought to be the worst case and the PF is a worst case PF.

The PF data are presented based upon predetermined PF pass levels, ranging from 2 to 10 (i.e., at each pass level the number of failing and passing suits is recorded). The higher the percentage of test occasions that passes at a given PF, the greater the probability that the suit will provide that level of protection in use.

## ACRONYMS and ABBREVIATIONS

Ct	Vapor exposure, product of vapor concentration (mg/m <sup>3</sup> ) and time (minutes)
C <sub>t</sub> t <sub>skin</sub> cm <sup>2</sup>	Vapor exposure to skin Square centimeters
°F	Temperature in degrees Fahrenheit
delta p	Differential pressure
DoD	Department of Defense
ECBC	U.S. Army Edgewood Chemical Biological Center
ERDEC	U.S. Army Edgewood Research, Development and Engineering Center
g	Gram
GB	Sarin, Isopropylmethylphosphonofluoridate
HD	Sulfur Mustard; 2,2'-Dichlorodiethylsulfide
L	Liter
M <sub>f</sub> m <sup>2</sup>	Cumulative mass permeation through the fabric Square meters
m <sup>3</sup>	Cubic meters
mg	Milligram
µL	Microliter
ng	Nanogram
NBC	Nuclear, Biological and Chemical
OSHA	Occupational Safety and Health Administration
PCT	Pre-concentrator tube
PF	Protection Factor
PPE	Personal Protective Equipment
P <sub>s</sub>	Skin permeability
RH	Relative Humidity
SCBA	Self-Contained Breathing Apparatus
TOP	Test Operations Procedure

Blank

## Appendix A

### Level B Suits Chosen for Testing

**Table A-1. Level B Suits Tested**

Model	Manufacturer	Address
TFR4 CB Protective Coverall (Tyvek F)	Remploy Limited	Salisbury, UK
Kappler ProShield 3 Coverall	Kappler Protective Apparel and Fabrics	Guntersville, AL
Kappler CPF1 Coverall	Kappler Protective Apparel and Fabrics	Guntersville, AL
Kappler CPF2 Coverall	Kappler Protective Apparel and Fabrics	Guntersville, AL
Kappler CPF4 Coverall	Kappler Protective Apparel and Fabrics	Guntersville, AL
Kappler Responder (41255-8A)	Kappler Protective Apparel and Fabrics	Guntersville, AL
Kappler Level B CSM Responder (42489)	Kappler Protective Apparel and Fabrics	Guntersville, AL

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## **Appendix B**

### **Modified Static Diffusion Test Procedure**

#### **MODIFIED STATIC DIFFUSION TEST**

This test procedure was adapted from Test Operations Procedure (TOP) 8-2-501, Permeation and Penetration of Air-Permeable, Semipermeable and Impermeable Materials with Chemical Agents or Simulants (Swatch Testing). U.S. Army Dugway Proving Ground, UT. 3 March 1997, UNCLASSIFIED Report (AD A322329). The test procedure was entitled “Semipermeable and Impermeable Materials Static Diffusion Penetration Testing (Liquid Agent Challenge/Vapor Penetration; delta p = 0, Single Flow Test)”. The following procedure was used:

1. Upon receipt of a suit, all available information concerning the suit will be recorded; date of manufacture, lot number, serial number, materials of construction, etc.
2. From each suit, three each 1 and 15/16-in diameter material swatches will be taken for mustard (HD) and a like number taken for sarin (GB). Depending upon the suit configuration, 3 seam swatches (same diameter) will be taken plus triplicate swatches of other flat components such as visor, gloves, suit/visor interface and zipper/material interface for HD and an equal number for GB. Each swatch will be placed in an airtight bag and given a unique serial number, which will be placed on the bag. A list of serial numbers will be kept with the swatches. Alternatively, the swatches for each day’s test will be cut from the suit and placed in the environmental chamber for conditioning. Sample identification will accompany each swatch.
3. The environmental chamber will be controlled at a temperature of 90 +/- 2 °F, and the maximum achievable relative humidity (RH) without occurrence of condensation (normally 50% +/- 10% RH). The temperature and RH readings will be checked weekly with a calibrated meter. The test cell air will be drawn from the chamber air. The TOP 8-2-501 specifies that a system control and data acquisition system will be used, but this system will not be used due to budget constraints. The temperature and RH will be recorded in a computer file. Flow rates will be manually recorded. The TOP 8-2-501 specifies that differential pressure monitoring will be done but differential pressure gages will not be used due to budget constraints.
4. The TOP test cell will be used. When assembling, the cell lugs will be tightened by hand to finger tight. The flow rate beneath each swatch will be 1 L/min, which will be controlled by a linear mass flow controller. The flows will be checked with a calibrated test meter weekly. Each test cell will be checked for leaks after assembly by connecting it to the vacuum source and checking that the inlet flow is the same as the outlet flow on the mass flow controller. If the flows don’t match, the test cell will be disassembled, adjustments made, the test cell reassembled and flows rechecked.
5. The TOP 8-2-501 specifies that positive control and negative control swatches will be used, but they will not be used due to budgetary and schedule limitations. The swatches will be preconditioned for at least 2 hr and will be monitored by MINICAM<sup>TM</sup> for at least one cycle prior to agent application. Eighty-mil silicone will be used, one for each test (six suit swatches and one silicone swatch).
6. Agents GB and HD will be used. The contamination density will be 10 g/m<sup>2</sup> (8 each 1 µL HD droplets or 10 each 1 µL GB droplets). A robotic agent application system is not available. The agent will be applied using the click/touch method with a repeating dispenser.

7. Seven swatches will be tested at once. MINICAMS™ with stream selection system will monitor vapor penetration with a 3-min cycle. There will be three sampling intervals following the silicone during which chamber air will be sampled. Each swatch will be sampled once every 30 min. The MINICAMS™ will be standardized weekly with a range of agent standards; concentrations will normally range from 1 ng/ $\mu$ L to 100 ng/ $\mu$ L.

8. The test length will be 24 hr.

9. The test cells and o-rings will be aerated between uses. No other cleaning method will be used.

10. The data to be reported are cumulative permeation ( $\text{ng}/\text{cm}^2$ ) at various elapsed times (minutes) for each swatch. The elapsed time for each swatch is the time from agent contamination. All recorded data will be placed in laboratory notebooks and one technical report per suit will be drafted at the conclusion of this effort.

## Appendix B

## **Appendix C**

### **Aerosol Simulant Test Procedure**

To properly test suits with statistical significance, eight suit ensembles of each model are provided to the Mask Fit Test Facility for examination. Each ensemble is new and inspected as received. The suit ensembles include relevant accessory equipment such respirators that are worn with the suits, gloves, boots, and any other equipment that is necessary for chemical agent use. The suit ensembles are run on at least 10 different subjects with at least 22 trials. The eight suits are reused to achieve the 22 or more trials. Sampling of suits is done at the neck and upper arm for each trial.

Exercise routine for all suits is as follows:

#### Phase 1 (Pre-Operational):

- 1) standing still, normal breathing
- 2) bending forward and touching toes
- 3) jogging in place
- 4) raising arms above head and looking upward
- 5) bending knees and squatting
- 6) crawling on hands and knees
- 7) torso twists with hands folded on chest
- 8) standing still, normal breathing

#### Phase 2 (Operational):

- 1) climb step ladder
- 2) move 3 lb boxes from table to floor
- 3) rest
- 4) roll walls and ceiling
- 5) bag clothes
- 6) rest
- 7) loosen bolts
- 8) move 3 lb boxes from floor to table

Note: The phase 1 (pre-operational) exercises are performed for 1 min each for a total of 8 min. The phase 2 (operational) exercises are performed for 4 min each for a total of 40 min.

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**APPENDIX D**

**TFR4 CB PROTECTIVE COVERALL (TYVEK F)**



**Figure D-1: TFR4 CB Protective Coverall - Front View**



**Figure D-2: TFR4 CB Protective Coverall - Side View**

## Appendix D

**Table D-1. TFR4 CB Protective Coverall - Average HD Permeation**

TFR4 CB Protective Coverall (Tyvek F)													
Time (min)	Suit Material	Time (min)	Suit Seam	Time (min)	Hood Material	Time (min)	Crotch Area	Time (min)	Hood Seam	Time (min)	Zipper/Material Interface	Average Time (min)	Weighted Average M <sub>f</sub>
5	0	14	0	14	0	14	0	5	0	5	0	10	0
35	4	44	0	44	0	44	119	35	1	35	8	40	14
65	7	74	0	74	0	74	626	65	1	65	48	70	69
95	10	104	0	104	0	104	1588	95	1	95	139	100	171
125	15	134	1	134	0	134	2753	125	1	125	272	130	297
155	23	164	5	164	0	164	3932	155	1	155	437	160	428
185	34	194	11	194	0	194	5090	185	1	185	624	190	560
215	47	224	19	224	0	224	6182	215	1	215	823	220	687
245	62	254	28	254	0	254	7185	245	1	245	1034	250	807
275	78	284	38	284	0	284	8126	275	1	275	1256	280	922
305	94	314	47	314	0	314	9026	305	1	305	1488	310	1034
335	110	344	56	344	0	344	9894	335	2	335	1731	340	1143
365	126	374	65	374	0	374	10727	365	4	365	1979	370	1248
395	142	404	75	404	0	404	11523	395	7	395	2231	400	1350
425	158	434	84	434	0	434	12287	425	8	425	2488	430	1449
455	173	464	92	464	0	464	13019	455	8	455	2751	460	1545
485	188	494	101	494	0	494	13727	485	8	485	3019	490	1638
515	203	524	110	524	0	524	14400	515	8	515	3289	520	1728
545	217	554	119	554	0	554	15032	545	8	545	3562		
575	231	584	127	584	0	584	15630	575	8	575	3836		
605	246	614	135	614	0	614	16205	605	8	605	4112		
635	259	644	144	644	0	644	16752	635	8	635	4392		
665	272	674	152	674	0	674	17269	665	8	665	4676		
695	285	704	160	704	0	704	17779	695	8	695	4974		
725	298	734	168	734	0	734	18286	725	8	725	5294		
755	311	764	175	764	0	764	18777	755	8	755	5624		
785	324	794	183	794	0	794	19241	785	8	785	5962		
815	336	824	190	824	0	824	19668	815	8	815	6303		
845	348	854	198	854	0	854	20063	845	8	845	6641		
875	359	884	205	884	0	884	20426	875	8	875	6975		
905	370	914	212	914	0	914	20754	905	8	905	7299		
935	380	944	219	944	0	944	21054	935	8	935	7611		
965	391	974	225	974	0	974	21325	965	8	965	7909		
995	401	1004	232	1004	0	1004	21567	995	8	995	8195		
1025	410	1034	238	1034	0	1034	21788	1025	8	1025	8474		
1055	420	1064	244	1064	0	1064	21989	1055	8	1055	8744		
1085	429	1094	251	1094	0	1094	22169	1085	8	1085	9005		
1115	438	1124	256	1124	0	1124	22335	1115	8	1115	9256		
1145	447	1154	262	1154	0	1154	22489	1145	8	1145	9502		
1175	456	1184	268	1184	0	1184	22630	1175	8	1175	9743		
1205	464	1214	274	1214	0	1214	22760	1205	8	1205	9978		
1235	473	1244	280	1244	0	1244	22879	1235	8	1235	10210		
1265	482	1274	286	1274	0	1274	22990	1265	8	1265	10433		
1295	491	1304	292	1304	0	1304	23094	1295	8	1295	10655		
1325	499	1334	299	1334	0	1334	23193	1325	8	1325	10879		
1355	507	1364	304	1364	0	1364	23285	1355	8	1355	11105		
1385	516	1394	309	1394	0	1394	23371	1385	8	1385	11327		
1415	523	1424	315	1424	0	1424	23452	1415	8	1415	11544		

Note 1: The time given for each sampling area is the average of the elapsed times for the three swatches tested per sampling area.

Note 2: The avg. time is the sum of the times given for each sampling area divided by the number of sampling areas.

Note 3: Weighted average M<sub>f</sub> = 0.5(Suit Matl M<sub>f</sub>) + 0.2(Suit Seam M<sub>f</sub>) + 0.1(Crotch Area M<sub>f</sub>) + 0.1(Hood Matl M<sub>f</sub>) + 0.05(Hood Seam M<sub>f</sub>) + 0.05(Zipper/Matl Interface M<sub>f</sub>).

## Appendix D

**Table D-2. TFR4 CB Protective Coverall - Average GB Permeation**

TFR4 CB Protective Coverall (Tyvek F)													
Time (min)	Suit Material	Time (min)	Suit Seam	Time (min)	Hood Material	Time (min)	Crotch Area	Time (min)	Hood Seam	Time (min)	Zipper/ Material Interface	Average Time (min)	Weighted Average $M_f$
5	1	14	1	5	1	15	3	14	4	14	0	11	1
35	6	44	62	35	11	45	112	44	1354	44	2957	41	243
65	6	74	158	65	44	75	449	74	3946	74	8876	71	725
95	6	104	223	95	104	105	910	104	6353	104	14855	101	1209
125	6	134	276	125	157	135	1352	134	8094	134	20943	131	1661
155	6	164	324	155	192	165	1748	164	8972	164	27059	161	2063
185	6	194	366	185	216	195	2102	194	9410	194	33193	191	2438
215	6	224	400	215	234	225	2420	224	9648	224	39372	221	2799
245	6	254	432	245	248	255	2707	254	9805	254	45542	251	3152
275	6	284	467	275	260	285	2968	284	9927	284	51704	281	3501
305	6	314	504	305	271	315	3206	314	10035	314	57867	311	3847
335	6	344	539	335	281	345	3426	344	10134	344	64023	341	4189
365	6	374	572	365	289	375	3627	374	10225	374	70192	371	4530
395	6	404	604	395	298	405	3814	404	10308	404	76392	401	4870
425	6	434	634	425	306	435	3989	434	10387	434	82609	431	5209
455	6	464	664	455	314	465	4155	464	10462	464	88813	461	5546
485	6	494	692	485	321	495	4310	494	10535	494	95006	491	5882
515	6	524	720	515	329	525	4456	524	10606	524	101207	521	6216
545	6	554	747	545	337	552	4575	554	10675				
575	6	584	774	575	343	573	4645	584	10742				
605	6	614	801	605	348	594	4698	614	10806				
635	6	644	826	635	353	615	4743	644	10867				
665	6	674	852	665	358	636	4783	674	10926				
695	6	704	876	695	363	657	4820	704	10983				
725	6	734	900	725	367	678	4853	734	11038				
755	6	764	924	755	369	699	4883	764	11090				
785	6	794	948	785	373	720	4912	794	11142				
815	6	824	971	815	376	741	4939	824	11191				
845	6	854	994	845	379	762	4965	854	11239				
875	6	884	1016	875	381	783	4989	884	11285				
905	6	914	1038	905	384	804	5011	914	11330				
935	6	944	1059	935	386	825	5033	944	11374				
965	6	974	1080	965	388	846	5053	974	11417				
995	6	1004	1100	995	391	867	5073	1004	11460				
1025	6	1034	1120	1025	393	888	5092	1034	11501				
1055	6	1064	1140	1055	395	909	5110	1064	11541				
1085	6	1094	1160	1085	397	930	5127	1094	11580				
1115	6	1124	1179	1115	398	951	5144	1124	11617				
1145	6	1154	1198	1145	398	972	5159	1154	11654				
1175	6	1184	1216	1175	398	993	5175	1184	11690				
1205	6	1214	1234	1205	398	1014	5189	1214	11724				
1235	6	1244	1251	1235	398	1035	5204	1244	11757				
1265	6	1274	1267	1265	398	1056	5217	1274	11787				
1295	6	1304	1283	1295	398	1077	5231	1304	11817				
1325	6	1334	1299	1325	398	1098	5243	1334	11847				
1355	6	1364	1314	1355	398	1119	5256	1364	11877				
1385	6	1394	1328	1385	398	1140	5268	1394	11905				
1415	6	1424	1342	1415	398	1156	5280	1424	11931				

Note 1: The time given for each sampling area is the average of the elapsed times for the three swatches tested per sampling area.

Note 2: The avg. time is the sum of the times given for each sampling area divided by the number of sampling areas.

Note 3: Weighted average  $M_f = 0.5(\text{Suit Matl } M_f) + 0.2(\text{Suit Seam } M_f) + 0.1(\text{Crotch Area } M_f) + 0.1(\text{Hood Matl } M_f) + 0.05(\text{Hood Seam } M_f) + 0.05(\text{Zipper/Matl Interface } M_f)$ .

## Appendix D

### TFR4 CB Protective Coverall (Tyvek F)

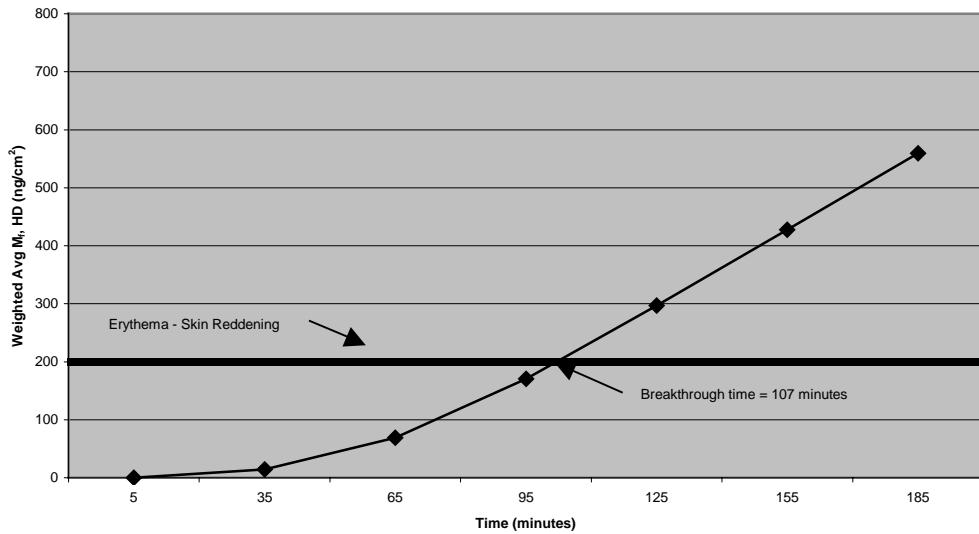


Figure D-3: TFR4 CB Protective Coverall - Weighted Average HD Permeation

### TFR4 CB Protective Coverall (Tyvek F)

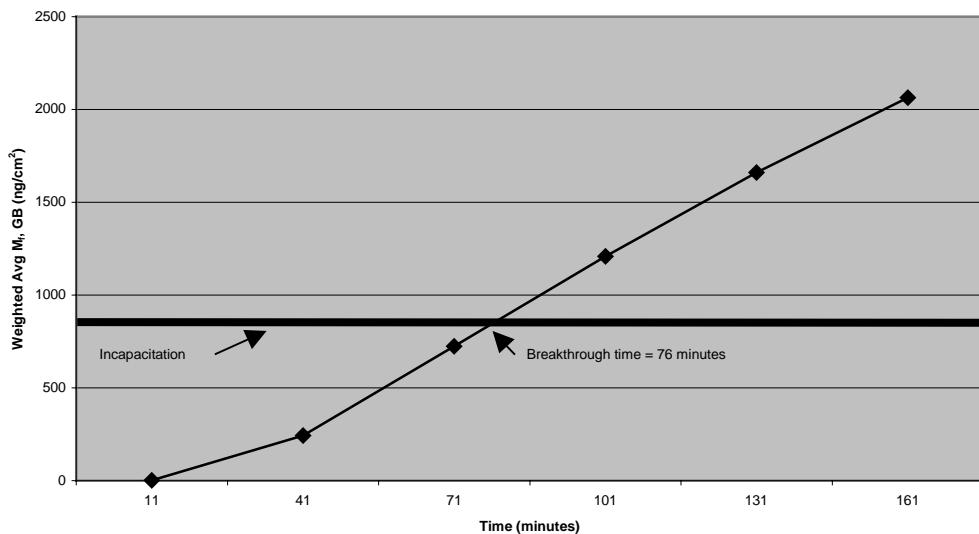
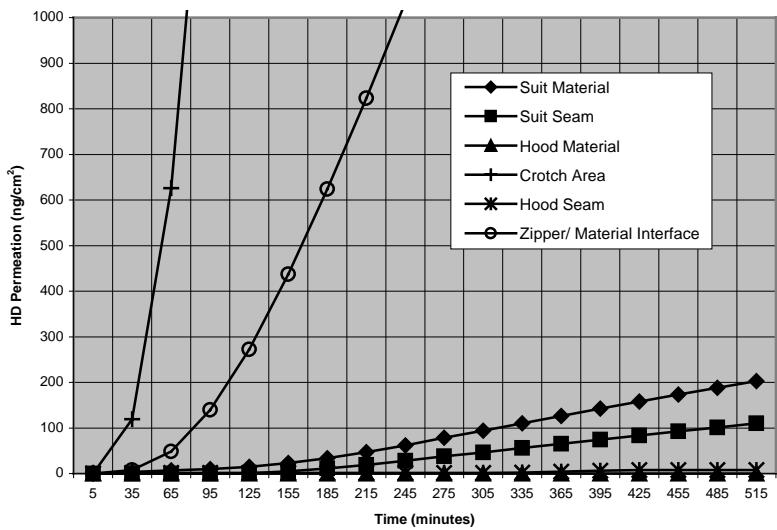
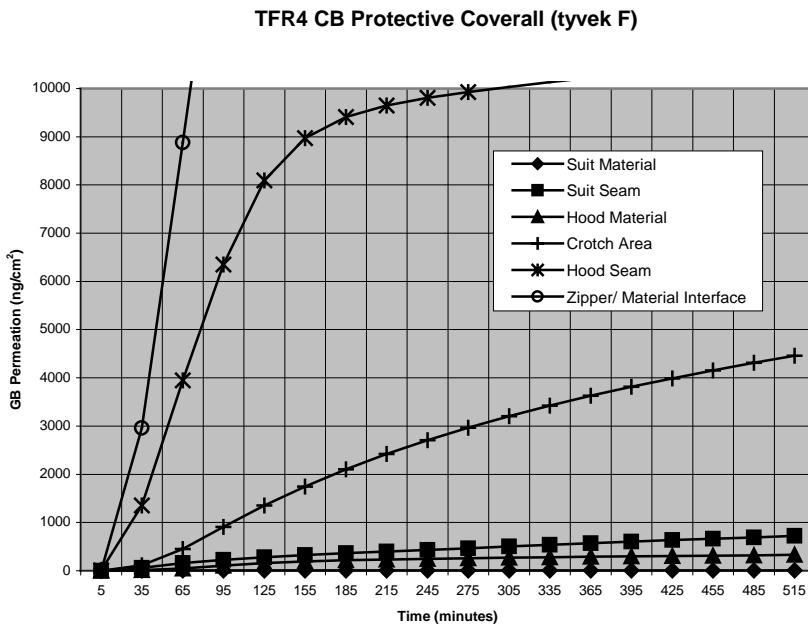


Figure D-4: TFR4 CB Protective Coverall - Weighted Average GB Permeation

**TFR4 CB Protective Coverall (Tyvek F)**



**Figure D-5: TFR4 CB Protective Coverall - HD Permeation by Sampling Area**



**Figure D-6: TFR4 CB Protective Coverall - GB Permeation by Sampling Area**

**Table D-3.TFR4 CB Protective Coverall - System Test (Aerosol Simulant) Results**

PF Range	Visor Region and Upper Arm, Combined					
	Pre-Operational Exercises			Operational Exercises		
	No. of Occasions in Range	Cumulative Rate, Percent	Cumulative Pass Rate, Percent	No. of Occasions in Range	Cumulative Rate, Percent	Cumulative Pass Rate, Percent
0	0	0	100	0	0	100
2	10	42	58	13	54	46
5	14	100	0	11	100	0
10	0	100	0	0	100	0
No. of Trials	24			24		

**Table D-4. TFR4 CB Protective Coverall - Overall Test Results**

Breakthrough Time (minutes)		Aerosol PF Pass Rate at PF Equal to:			Exercise Phase
Incapacitation	Erythema	2	5	10	
GB	HD	2	5	10	
76	107	58	0	0	Pre-Operational
		46	0	0	Operational

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## **APPENDIX E**

### **KAPPLER PROSHIELD 3 COVERALL**



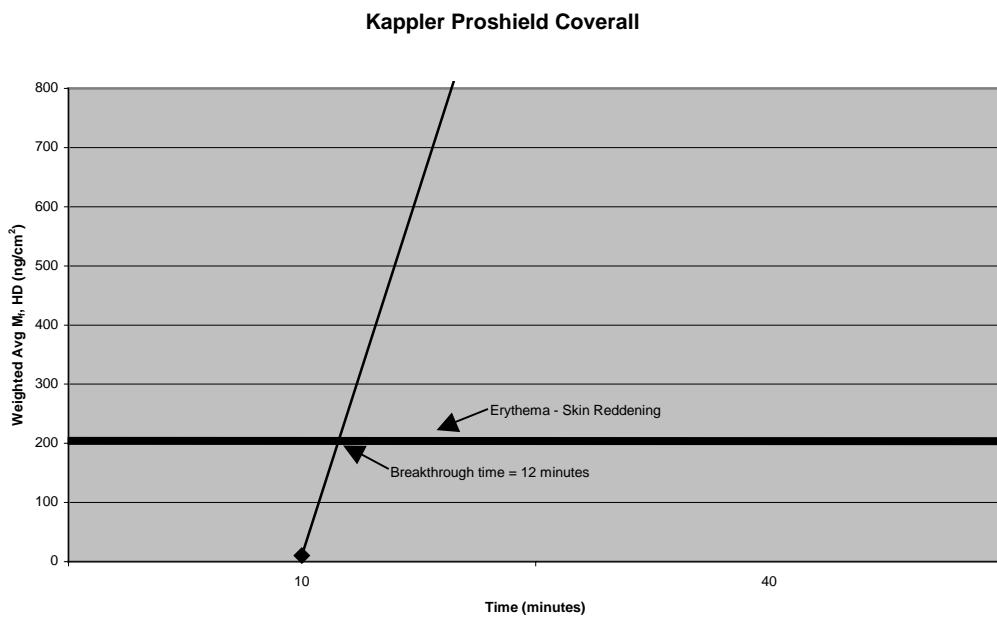
**Figure E-1: Kappler ProShield 3 - Front View**



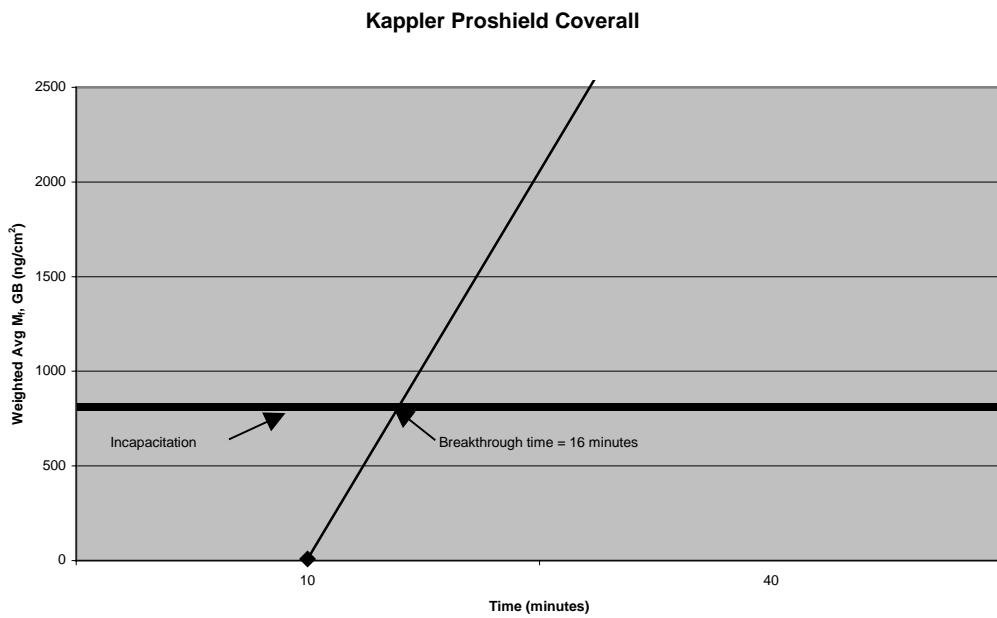
**Figure E-2: Kappler ProShield 3 - Side View**







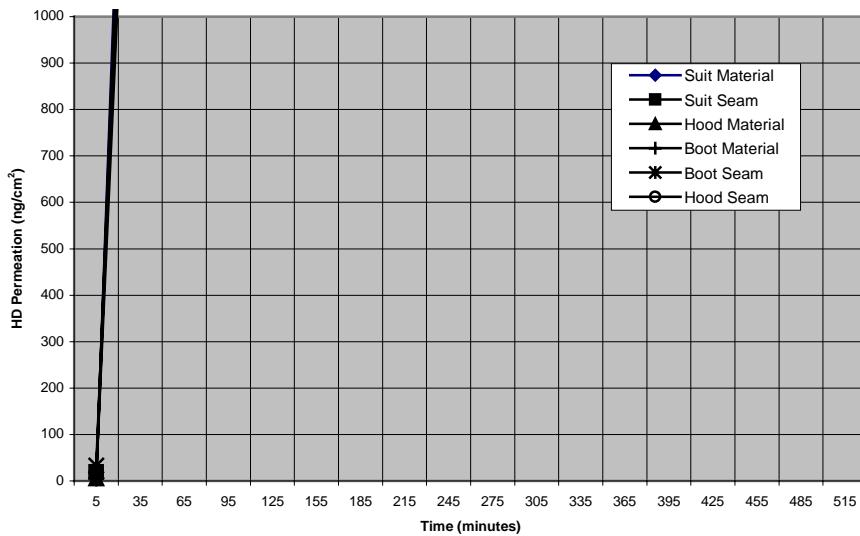
**Figure E-3: Kappler ProShield 3 - Weighted Average HD Permeation**



**Figure E-4: Kappler ProShield 3 - Weighted Average GB Permeation**

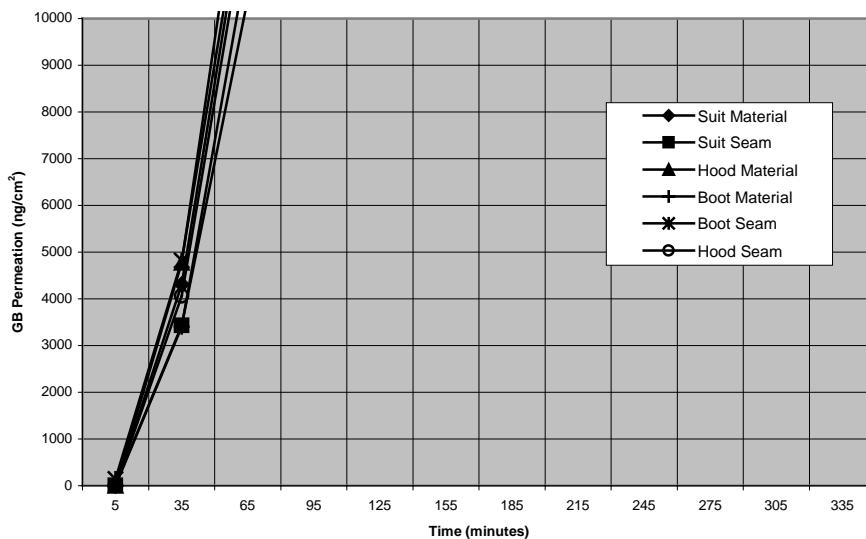
## Appendix E

### Kappler Proshield Coverall



**Figure E-5: Kappler ProShield 3 - HD Permeation by Sampling Area**

### Kappler Proshield Coverall



**Figure E-6: Kappler ProShield 3 - GB Permeation by Sampling Area**

**Table E-3. Kappler ProShield 3 - System Test (Aerosol Simulant) Results**

PF Range	Visor Region and Upper Arm, Combined					
	Pre-Operational Exercises			Operational Exercises		
	No. of Occasions in Range	Cumulative Rate, Percent	Cumulative Pass Rate, Percent	No. of Occasions in Range	Cumulative Rate, Percent	Cumulative Pass Rate, Percent
0	0	0	100	0	0	100
2	12	50	50	12	50	50
5	9	87	13	12	100	0
10	3	100	0	0	100	0
No. of Trials	24			24		

**Table E-4. Kappler ProShield 3 - Overall Test Results**

Breakthrough Time (minutes)		Aerosol PF Pass Rate at PF Equal to:			Exercise Phase
Incapacitation	Erythema	2	5	10	
GB	HD				
16	12	50	13	0	Pre-Operational
		50	0	0	Operational

Blank

## **APPENDIX F**

### **KAPPLER CPF1 COVERALL**



**Figure F-1: Kappler CPF1 Coverall - Front View**

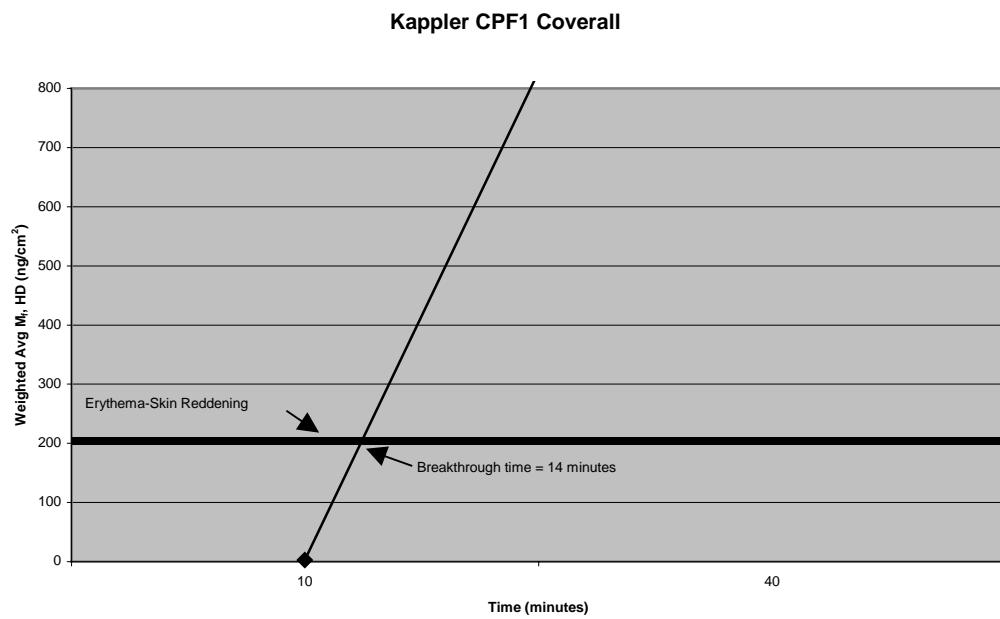


**Figure F-2: Kappler CPF1 Coverall - Side View**

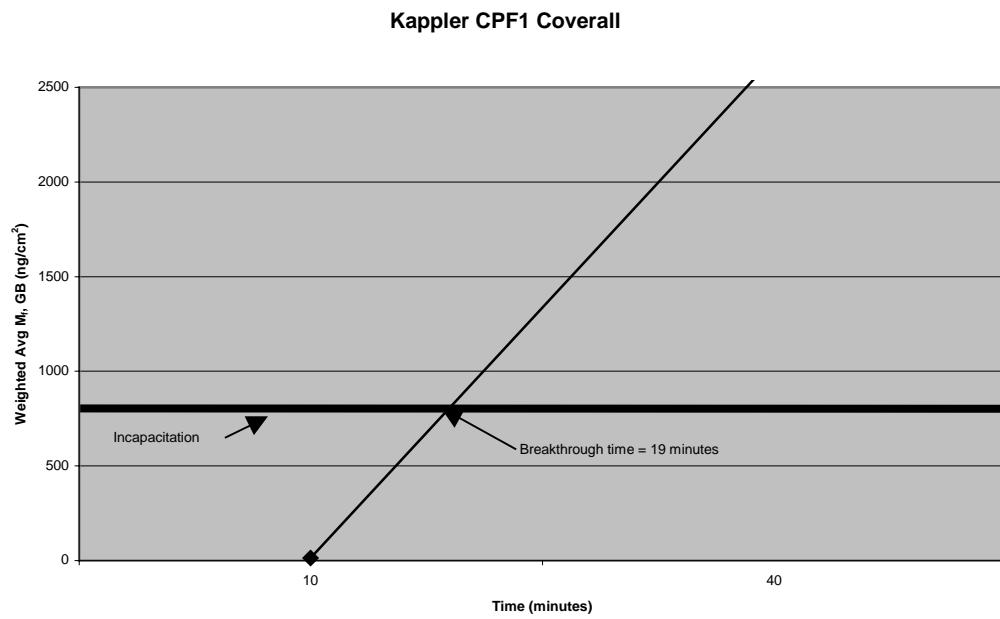
## Appendix F







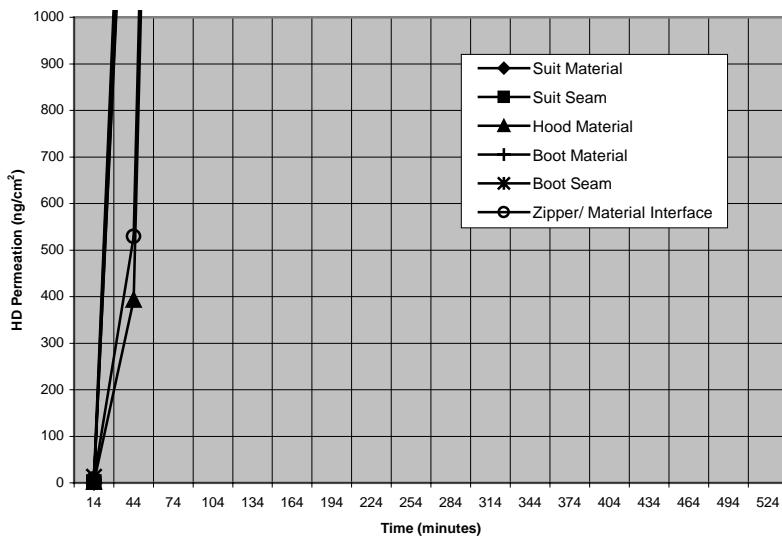
**Figure F-3: Kappler CPF1 - Weighted Average HD Permeation**



**Figure F-4: Kappler CPF1 - Weighted Average GB Permeation**

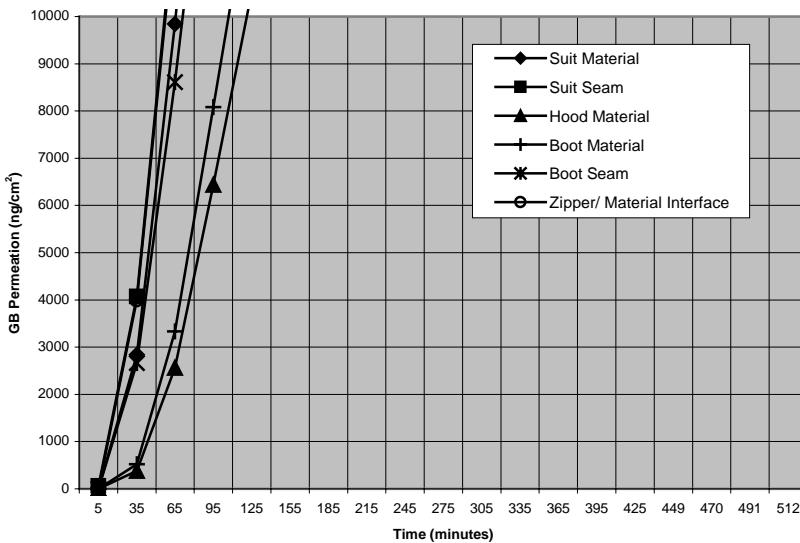
## Appendix F

### Kappler CPF1 Coverall



**Figure F-5: Kappler CPF1 - HD Permeation By Sampling Area**

### Kappler CPF1 Coverall



**Figure F-6: Kappler CPF1 - GB Permeation By Sampling Area**

**Table F-3. Kappler CPF1 Coverall - System Test (Aerosol Simulant) Results**

PF Range	Visor Region and Upper Arm, Combined					
	Pre-Operational Exercises			Operational Exercises		
	No. of Occasions in Range	Cumulative Rate, Percent	Cumulative Pass Rate, Percent	No. of Occasions in Range	Cumulative Rate, Percent	Cumulative Pass Rate, Percent
0	0	0	100	0	0	100
2	12	50	50	13	54	46
5	12	100	0	11	100	0
10	0	100	0	0	100	0
No. of Trials	24			24		

**Table F-4. Kappler CPF1 Coverall - Overall Test Results**

Breakthrough Time (minutes)		Aerosol PF Pass Rate at PF Equal to:			Exercise Phase
Incapacitation	Erythema	2	5	10	
GB	HD				
19	14	50	0	0	Pre-Operational
		46	0	0	Operational

Blank

**APPENDIX G**  
**KAPPLER CPF2 COVERALL**



**Figure G-1: Kappler CPF2 Coverall - Front View**



**Figure G-2: Kappler CPF2 Coverall - Side View**

## Appendix G



**Table G-2. Kappler CPF2 – Average GB Permeation**

Kappler CPF2 Coverall													
Time (min)	Suit Material	Time (min)	Suit Seam	Time (min)	Hood Material	Time (min)	Boot Material	Time (min)	Boot Seam	Time (min)	Zipper/ Material Interface	Average Time (min)	Weighted Average $M_f$
5	2	14	4	5	0	5	2	14	7	14	0	10	2
35	18	44	4174	35	2	35	47	44	3368	44	3813	40	1208
65	130	74	12507	65	159	65	308	74	10138	74	11368	70	3688
95	346	104	20870	95	468	95	773	104	17122	104	18678	100	6261
125	554	134	29268	125	764	125	1236	134	24382	134	25624	130	8831
155	740	164	37694	155	1033	155	1661	164	31877	164	32175	160	11380
185	908	194	46094	185	1276	185	2043	194	39538	194	38339	190	13899
215	1057	224	54337	215	1497	215	2391	224	47324	224	44127	220	16357
245	1188	254	62280	245	1702	245	2710	254	55203	254	49576	250	18730
275	1305	284	69745	275	1890	275	3001	284	63123	284	54714	280	20983
305	1412	314	76635	305	2063	305	3270	314	71003	314	59511	310	23092
335	1509	344	83019	335	2224	335	3514	344	78731	344	63999	340	25069
365	1597	374	88877	365	2376	365	3735	374	86243	374	68225	370	26909
395	1677	404	94213	395	2518	395	3939	404	93474	404	72214	400	28611
425	1750	434	99069	425	2650	425	4125	434	100348	434	76008	430	30184
455	1816			455	2774	455	4294				464	79577	
482	1868			485	2889	479	4408				494	82926	
506	1906			515	2995	500	4478				524	86109	
527	1930			545	3096	521	4529				554	89126	
548	1947			575	3192	542	4574						
569	1962			602	3269	563	4616						
590	1974			629	3335	584	4654						
611	1986			656	3396	605	4690						
632	1997			680	3441	626	4726						
653	2007			704	3477	647	4761						
674	2016			728	3510	668	4796						
695	2025			752	3540	689	4830						
716	2033			776	3569	710	4863						
737	2041			800	3597	731	4895						
758	2049			824	3624	752	4926						
779	2056			848	3649	773	4956						
800	2064			872	3674	794	4986						
821	2070			896	3698	815	5014						
842	2077			920	3721	836	5041						
863	2083			944	3744	857	5068						
884	2089			968	3766	878	5093						
905	2096			992	3789	899	5117						
926	2101			1016	3810	920	5141						
947	2107			1040	3831	941	5164						
968	2113			1064	3851	962	5186						
989	2119			1088	3872	983	5208						
1010	2125			1112	3892	1004	5229						
1031	2132			1136	3911	1025	5250						
1052	2138			1160	3929	1046	5270						
1073	2145			1184	3947	1067	5291						
1094	2151			1208	3965	1088	5311						
1115	2156			1232	3982	1109	5331						
1136	2161			1256	3999	1130	5349						

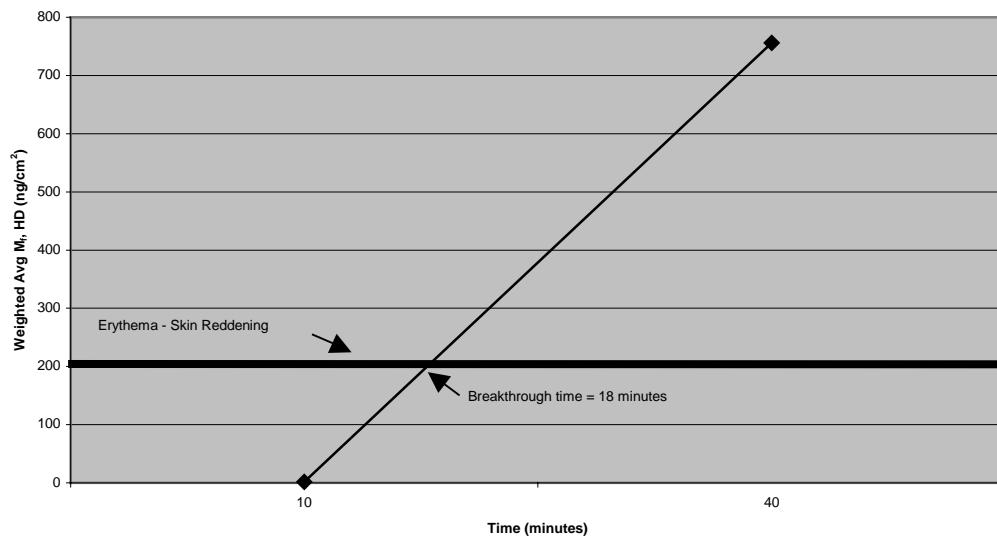
Note 1: The time given for each sampling area is the average of the elapsed times for the three swatches tested per sampling area.

Note 2: The avg. time is the sum of the times given for each sampling area divided by the number of sampling areas.

Note 3: Weighted average  $M_f = 0.5(\text{Suit Matl } M_f) + 0.2(\text{Suit Seam } M_f) + 0.1(\text{Boot Matl } M_f) + 0.1(\text{Hood Matl } M_f) + 0.05(\text{Boot Seam } M_f) + 0.05(\text{Zipper/Matl Interface } M_f)$ .

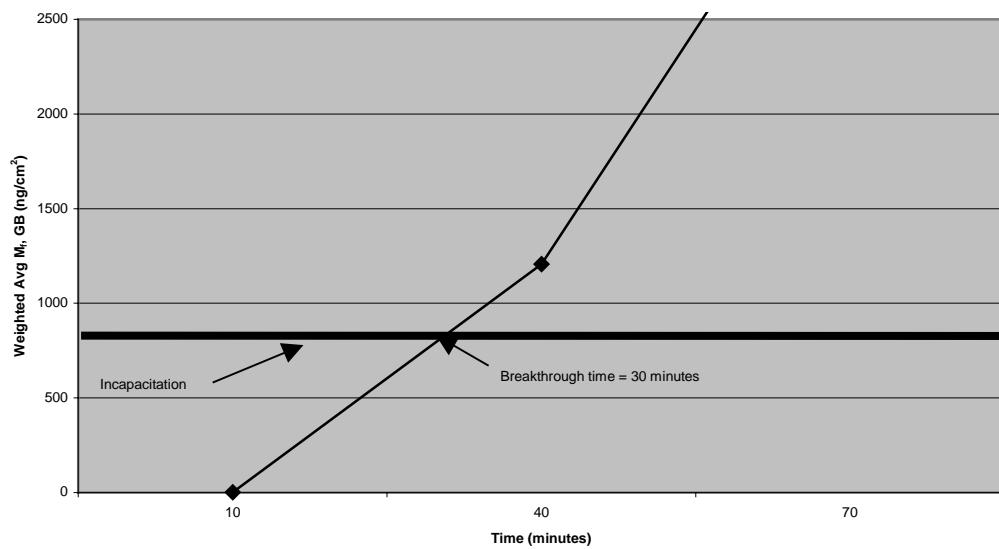
## Appendix G

**Kappler CPF2 Coverall**



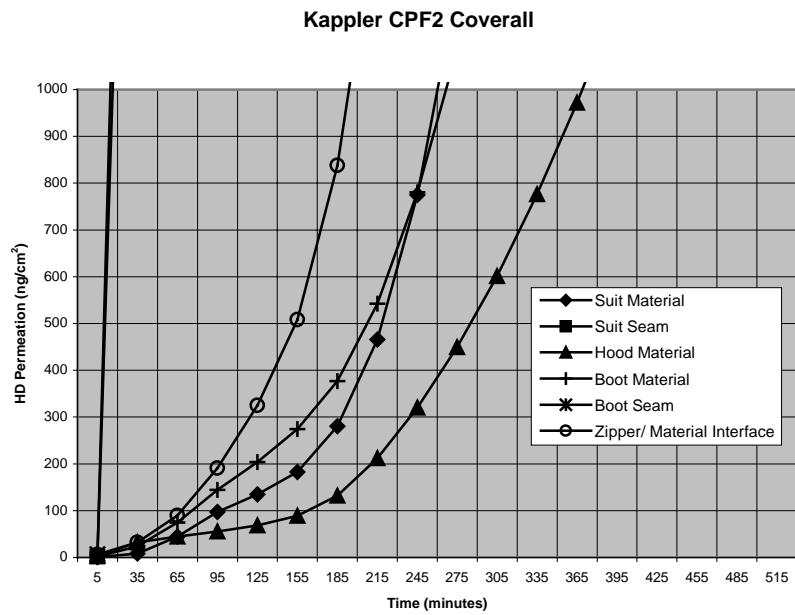
**Figure G-3: Kappler CPF2 - Weighted Average HD Permeation**

**Kappler CPF2 Coverall**

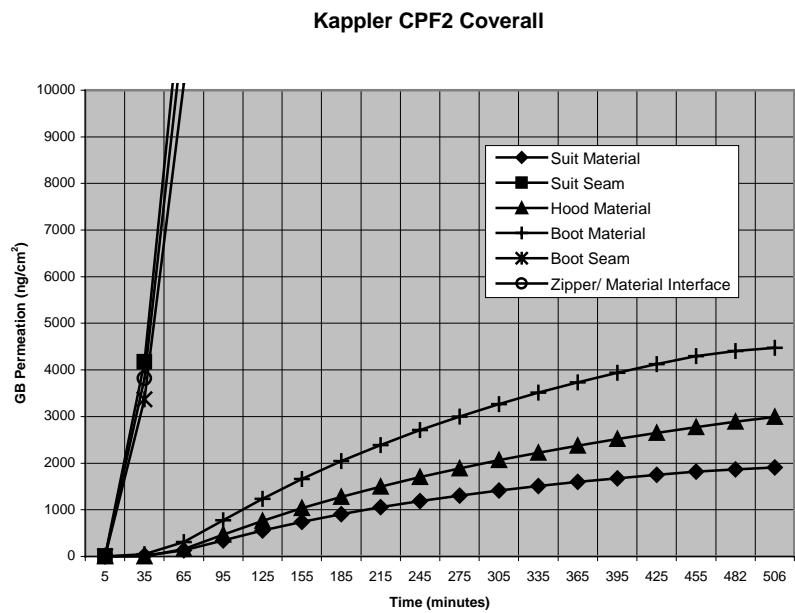


**Figure G-4: Kappler CPF2 - Weighted Average GB Permeation**

## Appendix G



**Figure G-5: Kappler CPF2 - HD Permeation by Sampling Area**



**Figure G-6: Kappler CPF2 - GB Permeation by Sampling Area**

Appendix G

**Table G-3. Kappler CPF2 - System Test (Aerosol Simulant) Results**

PF Range	Visor Region and Upper Arm, Combined					
	Pre-Operational Exercises			Operational Exercises		
	No. of Occasions in Range	Cumulative Rate, Percent	Cumulative Pass Rate, Percent	No. of Occasions in Range	Cumulative Rate, Percent	Cumulative Pass Rate, Percent
0	0	0	100	0	0	100
2	12	50	50	12	50	50
5	9	87	13	12	100	0
10	3	100	0	0	100	0
No. of Trials	24			24		

**Table G-4. Kappler CPF2 - Overall Test Results**

Breakthrough Time (minutes)		Aerosol PF Pass Rate at PF Equal to:			Exercise Phase
Incapacitation	Erythema	2	5	10	
GB	HD				
30	18	50 50	13 0	0 0	Pre-Operational Operational

Blank

**APPENDIX H**  
**KAPPLER CPF4 COVERALL**



**Figure H-1: Kappler CPF4 - Front View**

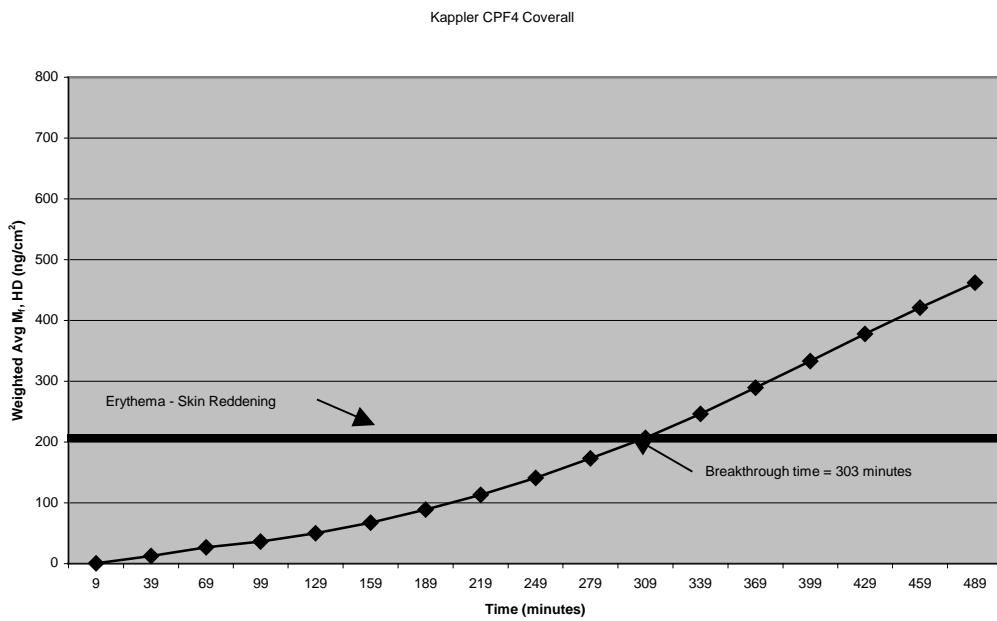


**Figure H-2: Kappler CPF4 - Side View**

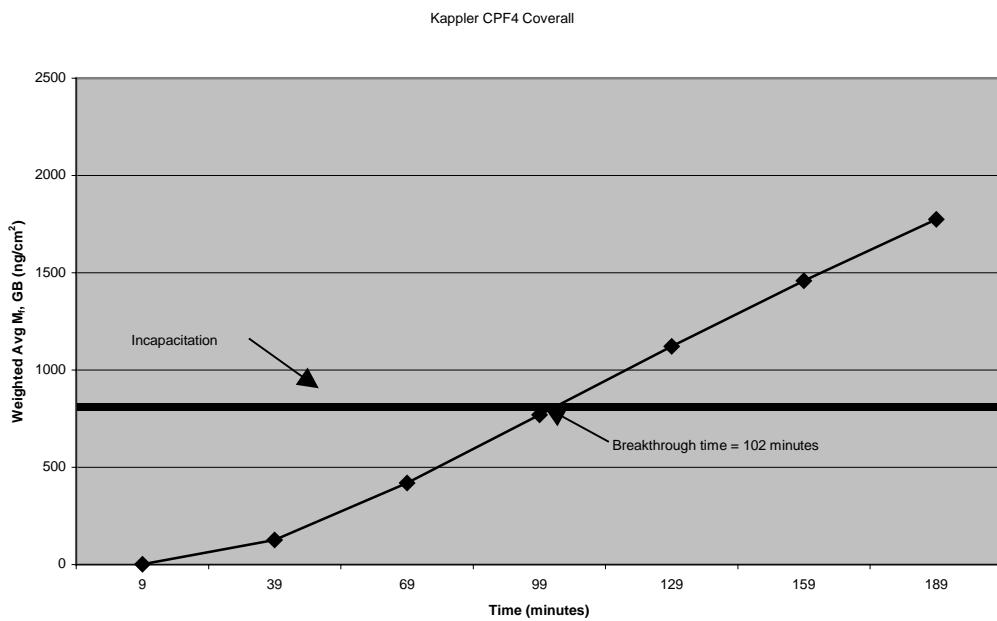
## Appendix H





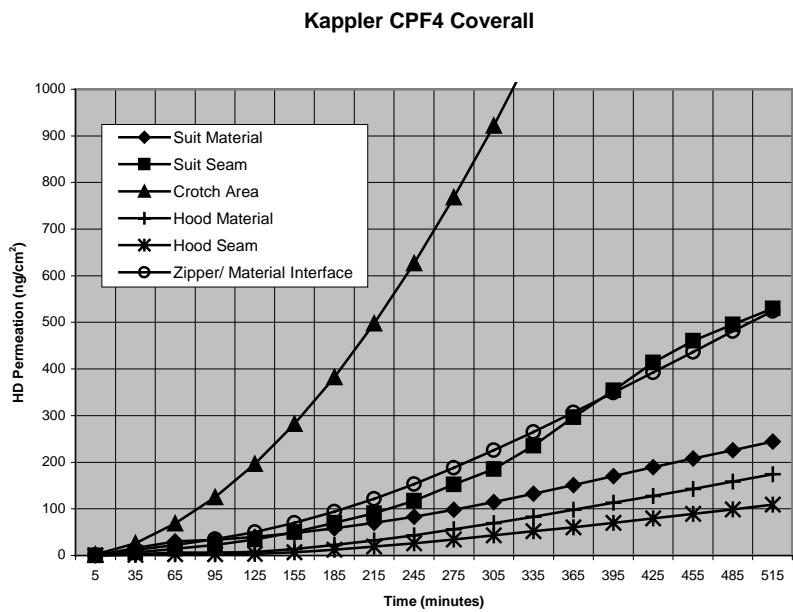


**Figure H-3: Kappler CPF4 - Weighted Average HD Permeation**

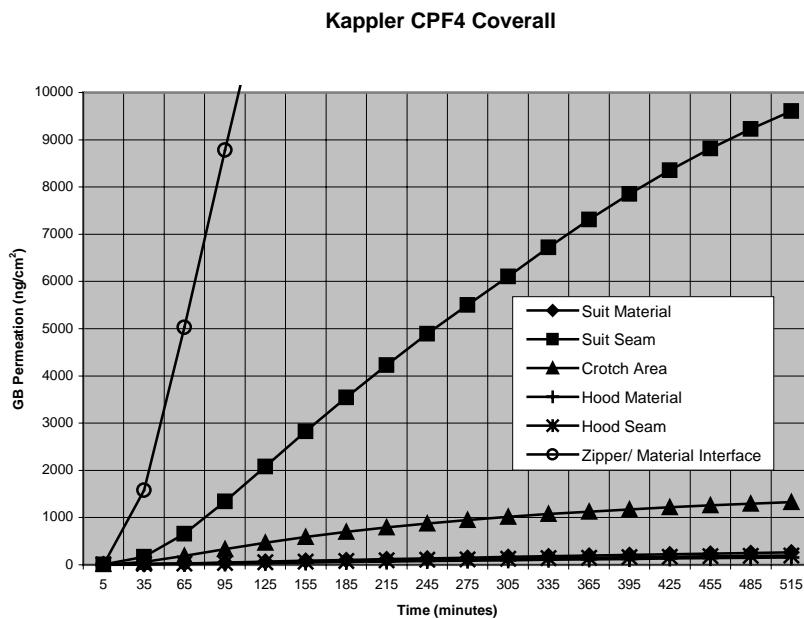


**Figure H-4: Kappler CPF4 - Weighted Average GB Permeation**

## Appendix H



**Figure H-5: Kappler CPF4 - HD Permeation by Sampling Area**



**Figure H-6: Kappler CPF4 - GB Permeation by Sampling Area**

**Table H-3. Kappler CPF4 - System Test (Aerosol Simulant) Results**

PF Range	Visor Region and Upper Arm, Combined					
	Pre-Operational Exercises			Operational Exercises		
	No. of Occasions in Range	Cumulative Rate, Percent	Cumulative Pass Rate, Percent	No. of Occasions in Range	Cumulative Rate, Percent	Cumulative Pass Rate, Percent
0	0	0	100	0	0	100
2	13	50	50	12	54	46
5	11	100	0	12	100	0
10	0	100	0	0	100	0
No. of Trials	24			24		

**Table H-4. Kappler CPF4 - Overall Test Results**

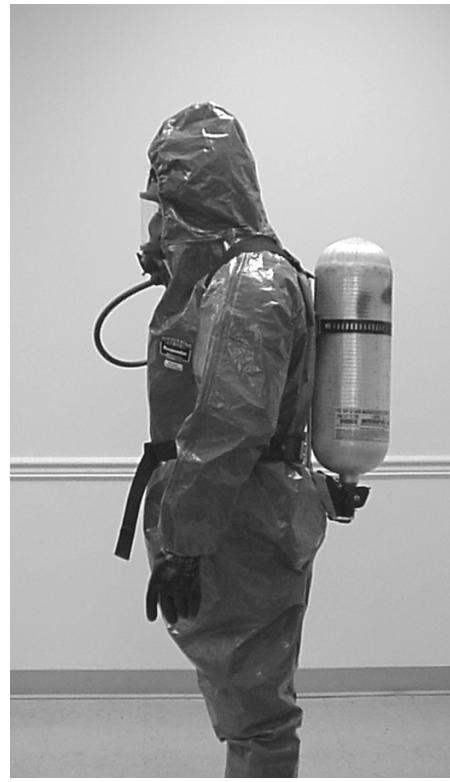
Breakthrough Time (minutes)		Aerosol PF Pass Rate at PF Equal to:			Exercise Phase
Incapacitation	Erythema	2	5	10	
GB	HD				
102	303	50	0	0	Pre-Operational
		46	0	0	Operational

Blank

APPENDIX I  
KAPPLER RESPONDER (41255-8A)



**Figure I-1: Kappler Responder – Front View**



**Figure I-2: Kappler Responder - Side View**

## Appendix I

**Table I-1. Kappler Responder - Average HD Permeation**

Kappler Responder 412558A													
Time (min)	Suit Material	Time (min)	Suit Seam	Time (min)	Hood Material	Time (min)	Boot Material	Time (min)	Boot Seam	Time (min)	Zipper/ Material Interface	Average Time (min)	Weighted Average $M_f$
6	2	15	4	4	1	4	9	13	12	13	4	9	4
36	37	45	28	34	26	34	164	43	70	43	23	39	48
66	82	75	56	64	59	64	336	73	128	73	50	69	100
96	132	105	85	94	99	94	508	103	187	103	85	99	157
126	187	135	119	124	146	124	680	133	249	133	133	129	219
156	246	165	155	154	200	154	847	163	312	163	192	159	284
186	309	195	194	184	261	184	1011	193	376	193	261	189	352
216	374	225	235	214	326	214	1173	223	442	223	339	219	423
246	442	255	278	244	395	244	1332	253	509	253	425	249	496
276	513	285	324	274	467	274	1488	283	576	283	518	279	572
306	587	315	371	304	541	304	1640	313	644	313	615	309	649
336	662	345	419	334	616	334	1789	343	712	343	716	339	727
366	739	375	469	364	691	364	1936	373	780	373	821	369	806
396	817	405	521	394	765	394	2080	403	849	403	929	399	886
426	897	435	573	424	841	424	2220	433	916	433	1041	429	967
456	977	465	626	454	916	454	2356	463	983	463	1156	459	1048
486	1056	495	679	484	993	484	2489	493	1050	493	1274	489	1128
516	1135	525	732	514	1069	514	2618	523	1117	523	1395	519	1208
546	1215	555	786	544	1146	544	2744	553	1183	553	1519	549	1289
576	1296	585	841	574	1223	574	2868	583	1249	583	1646	579	1370
606	1376	615	895	604	1300	604	2989	613	1314	613	1774	609	1450
636	1455	645	950	634	1377	634	3107	643	1379	643	1905	639	1530
666	1536	675	1006	664	1454	664	3224	673	1443	673	2038	669	1611
696	1618	705	1061	694	1531	694	3337	703	1507	703	2174	699	1692
726	1698	735	1117	724	1608	724	3451	733	1571	733	2312	729	1773
756	1779	765	1174	754	1685	754	3563	763	1635	763	2450	759	1853
786	1859	795	1230	784	1761	784	3674	793	1699	793	2589	789	1933
816	1940	825	1286	814	1835	814	3784	823	1763	823	2728	819	2014
846	2020	855	1343	844	1909	844	3893	853	1826	853	2867	849	2093
876	2099	885	1399	874	1982	874	3998	883	1889	883	3007	879	2172
906	2178	915	1455	904	2055	904	4103	913	1951	913	3148	909	2251
936	2257	945	1512	934	2128	934	4206	943	2012	943	3291	939	2329
966	2334	975	1568	964	2201	964	4306	973	2072	973	3433	969	2407
996	2412	1005	1623	994	2272	994	4404	1003	2131	1003	3577	999	2484
1026	2489	1035	1679	1024	2343	1024	4501	1033	2191	1033	3721	1029	2560
1056	2564	1065	1734	1054	2414	1054	4597	1063	2250	1063	3866	1059	2636
1086	2640	1095	1789	1084	2484	1084	4692	1093	2308	1093	4010	1089	2711
1116	2715	1125	1844	1114	2554	1114	4786	1123	2367	1123	4154	1119	2787
1146	2790	1155	1898	1144	2624	1144	4880	1153	2425	1153	4299	1149	2861
1176	2864	1185	1953	1174	2694	1174	4972	1183	2484	1183	4442	1179	2936
1206	2938	1215	2006	1204	2763	1204	5065	1213	2543	1213	4585	1209	3009
1236	3010	1245	2059	1234	2832	1234	5157	1243	2602	1243	4727	1239	3082
1266	3082	1275	2113	1264	2900	1264	5248	1273	2661	1273	4868	1269	3155
1296	3153	1305	2166	1294	2968	1294	5337	1303	2718	1303	5010	1299	3227
1326	3223	1335	2219	1324	3036	1324	5425	1333	2774	1333	5150	1329	3298
1353	3283	1362	2265	1354	3103	1354	5512	1363	2830	1363	5289	1358	3362
1380	3340	1389	2309	1384	3171	1384	5598	1393	2886	1393	5427	1387	3424
1407	3396	1416	2353	1414	3238	1414	5684	1423	2942	1423	5563	1416	3486

Note 1: The time given for each sampling area is the average of the elapsed times for the three swatches tested per sampling area.

Note 2: The avg. time is the sum of the times given for each sampling area divided by the number of sampling areas.

Note 3: Weighted average  $M_f = 0.5(\text{Suit Matl } M_f) + 0.2(\text{Suit Seam } M_f) + 0.1(\text{Boot Matl } M_f) + 0.1(\text{Hood Matl } M_f) + 0.05(\text{Boot Seam } M_f) + 0.05(\text{Zipper/Matl Interface } M)$ .

## Appendix I

**Table I-2. Kappler Responder - Average GB Permeation**

Kappler Responder 412558A													
Time (min)	Suit Material	Time (min)	Suit Seam	Time (min)	Hood Material	Time (min)	Boot Material	Time (min)	Boot Seam	Time (min)	Zipper/ Material Interface	Average Time (min)	Weighted Average $M_f$
4	0	13	2	4	0	6	0	15	1	13	0	9	1
34	4	43	12	34	4	36	3	45	62	43	1439	39	80
64	10	73	22	64	17	66	10	75	214	73	4697	69	257
94	16	103	31	94	38	96	19	105	402	103	8261	99	453
124	22	133	43	124	62	126	28	135	590	133	11648	129	640
154	27	163	54	154	88	156	36	165	768	163	14813	159	816
184	34	193	65	184	112	186	43	195	932	193	17694	189	977
214	40	223	74	214	135	216	50	225	1079	223	20264	219	1121
244	46	253	82	244	157	246	56	255	1210	253	22596	249	1251
274	52	283	89	274	176	276	62	285	1326	283	24730	279	1371
304	58	313	95	304	195	306	66	315	1428	313	26680	309	1480
334	63	343	102	334	213	336	69	345	1521	343	28464	339	1579
364	67	373	108	364	230	366	73	375	1606	373	30080	369	1669
394	71	403	113	394	246	396	76	405	1682	403	31545	399	1751
424	74	433	118	424	260	426	78	435	1752	433	32893	429	1827
454	78	463	123	454	275	456	82	465	1815	463	34127	459	1896
484	82	493	127	484	288	486	84	495	1872	493	35253	489	1960
514	86	523	132	514	301	516	86	525	1924	523	36300	519	2019
544	90	553	136	544	314	546	88	555	1972	553	37280	549	2075
574	94	583	140	574	326	576	89	585	2018	583	38184	579	2127
604	98	613	144	604	338	606	91	615	2061	613	39013	609	2174
634	101	643	148	634	349	636	93	645	2101	643	39773	639	2218
664	105	673	152	664	361	666	94	675	2137	673	40466	669	2259
694	109	703	156	694	371	696	96	705	2171	703	41109	699	2296
724	113	733	159	724	381	726	97	735	2203	733	41707	729	2332
754	118	763	163	754	391	756	99	765	2232	763	42262	759	2365
784	122	793	166	784	401	786	100	795	2258	793	42774	789	2396
814	126	823	170	814	410	816	102	825	2282	823	43248	819	2425
844	131	853	173	844	420	846	104	855	2305	853	43688	849	2452
874	135	883	176	874	428	876	105	885	2326	883	44091	879	2477
904	139	913	178	904	438	906	106	915	2346	913	44464	909	2500
934	143	943	180	934	446	936	108	945	2364	943	44811	939	2522
964	147	973	181	964	454	966	109	975	2381	973	45133	969	2542
994	151	1003	183	994	463	996	111	1005	2398	1003	45433	999	2561
1024	155	1033	185	1024	471	1026	112	1035	2413	1033	45712	1029	2579
1054	159	1063	187	1054	479	1056	113	1065	2428	1063	45973	1059	2596
1084	163	1093	188	1084	486	1086	115	1095	2441	1093	46218	1089	2612
1114	167	1123	190	1114	493	1116	116	1125	2454	1123	46448	1119	2627
1144	171	1153	192	1144	501	1146	117	1155	2466	1153	46667	1149	2642
1174	174	1183	194	1174	508	1176	119	1185	2478	1183	46876	1179	2656
1204	178	1213	195	1204	515	1206	120	1215	2489	1213	47075	1209	2670
1234	182	1243	197	1234	522	1236	121	1245	2500	1243	47264	1239	2683
1264	186	1273	199	1264	529	1266	122	1275	2511	1273	47442	1269	2695
1294	189	1303	200	1294	536	1296	123	1305	2523	1303	47612	1299	2707
1324	193	1333	202	1324	542	1326	123	1335	2536	1333	47773	1329	2719
1354	196	1363	203	1354	548	1356	123	1365	2549	1363	47926	1359	2730
1384	200	1393	205	1384	554	1386	123	1395	2564	1393	48073	1389	2741
1414	204	1423	206	1414	560	1416	123	1425	2580	1423	48215	1419	2751

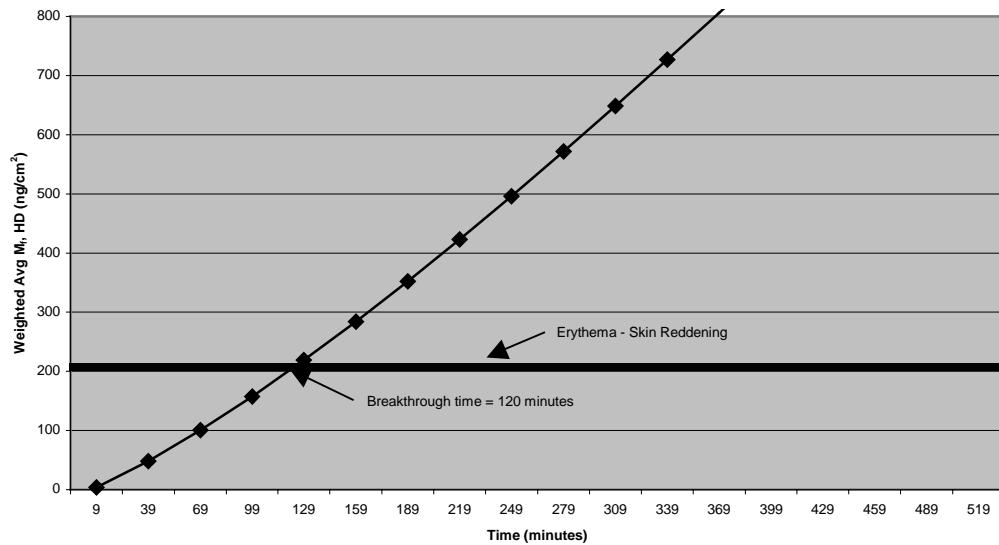
Note 1: The time given for each sampling area is the average of the elapsed times for the three swatches tested per sampling area.

Note 2: The avg. time is the sum of the times given for each sampling area divided by the number of sampling areas.

Note 3: Weighted average  $M_f = 0.5(\text{Suit Matl } M_f) + 0.2(\text{Suit Seam } M_f) + 0.1(\text{Boot Matl } M_f) + 0.05(\text{Hood Matl } M_f) + 0.05(\text{Boot Seam } M_f) + 0.05(\text{Zipper/Matl Interface } M)$ .

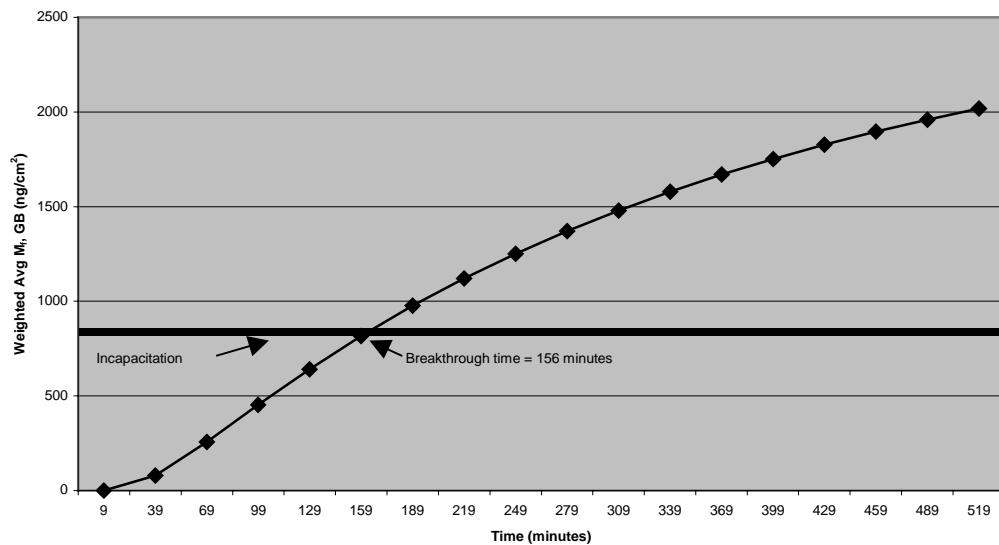
## Appendix I

**Kappler Responder 412558A**



**Figure I-3: Kappler Responder - Weighted Average HD Permeation**

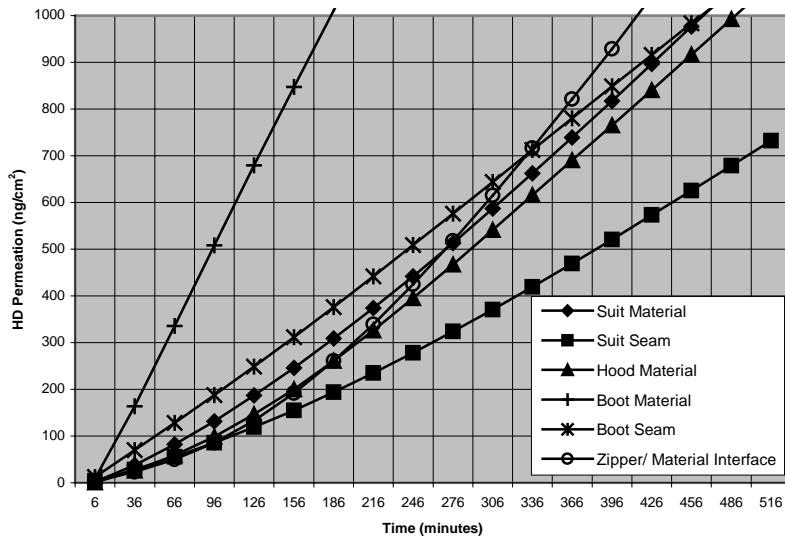
**Kappler Responder 412558A**



**Figure I-4: Kappler Responder - Weighted Average GB Permeation**

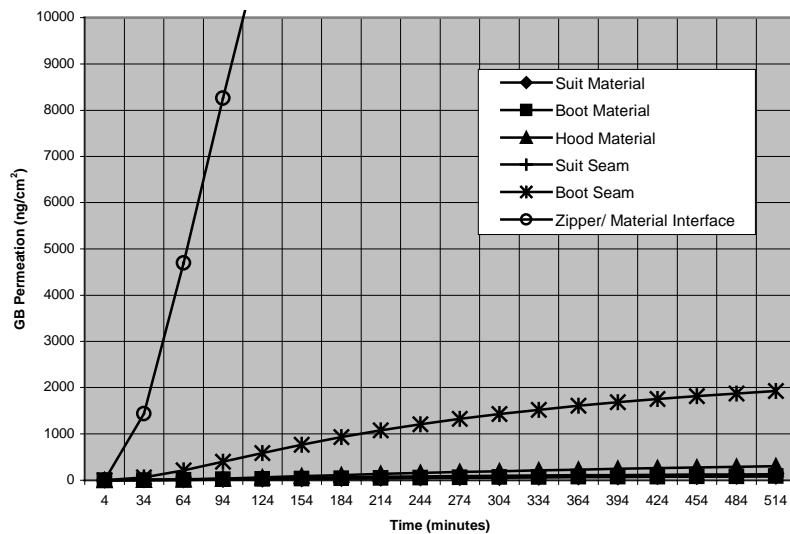
**Appendix I**

**Kappler Responder 412558A**



**Figure I-5: Kappler Responder - HD Permeation by Sampling Area**

**Kappler Responder 412558A**



**Figure I-6: Kappler Responder - GB Permeation by Sampling Area**

Appendix I

**Table I-3: Kappler Responder - System Test (Aerosol Simulant) Results**

PF Range	Visor Region and Upper Arm, Combined					
	Pre-Operational Exercises			Operational Exercises		
	No. of Occasions in Range	Cumulative Rate, Percent	Cumulative Pass Rate, Percent	No. of Occasions in Range	Cumulative Rate, Percent	Cumulative Pass Rate, Percent
0	0	0	100	0	0	100
2	14	58	42	19	79	21
5	10	100	0	5	100	0
10	0	100	0	0	100	0
No. of Trials	24			24		

**Table I-4. Kappler Responder - Overall Test Results**

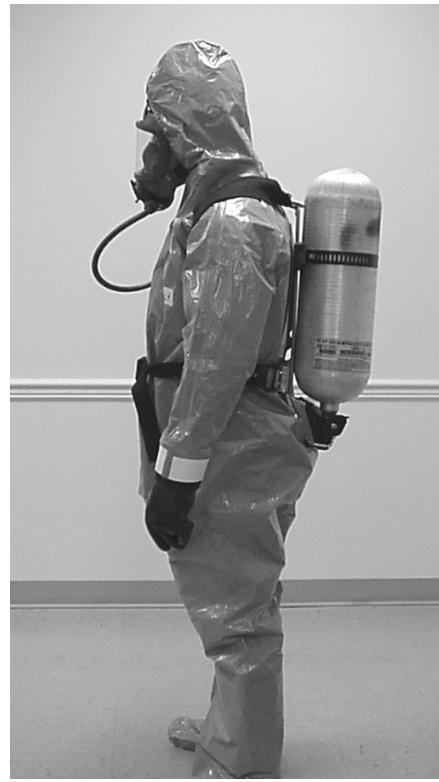
Breakthrough Time (minutes)		Aerosol PF Pass Rate at PF Equal to:			Exercise Phase
Incapacitation	Erythema	2	5	10	
GB	HD				
156		42	0	0	Pre-Operational
		21	0	0	Operational

Blank

**APPENDIX J**  
**KAPPLER LEVEL B CSM RESPONDER**



**Figure J-1: Kappler Level B CSM Responder –  
Front View**



**Figure J-2: Kappler Level B CSM Responder -  
Side View**

Appendix J

**Table J-1. Kappler Level B CSM Responder - Average HD Permeation**

Kappler Level B CSM Responder (42489)													
Time (min)	Suit Material	Time (min)	Suit Seam	Time (min)	Glove Material	Time (min)	Boot Material	Time (min)	Boot Seam	Time (min)	Zipper/ Material Interface	Average Time (min)	Weighted Average $M_f$
5	0	14	0	5	0	4	4	13	15	14	1	9	1
35	0	44	1	35	4	34	73	43	109	44	6	39	14
65	0	74	2	65	4	64	175	73	224	74	47	69	32
95	0	104	2	95	5	94	289	103	348	104	252	99	60
125	2	134	2	125	9	124	415	133	480	134	715	129	104
155	9	164	3	155	18	154	547	163	615	164	1419	159	163
185	20	194	9	185	29	184	685	193	752	194	2276	189	235
215	35	224	16	215	44	214	828	223	890	224	3209	219	313
245	53	254	25	245	61	244	974	253	1030	254	4184	249	396
275	73	284	35	275	79	274	1122	283	1169	284	5169	279	481
305	93	314	45	305	98	304	1272	313	1309	314	6156	309	566
335	115	344	56	335	117	334	1425	343	1450	344	7136	339	652
365	136	374	66	365	136	364	1578	373	1591	374	8097	369	737
395	157	404	77	395	154	394	1730	403	1730	404	9054	399	821
425	178	434	87	425	172	424	1880	433	1868	434	9997	429	905
455	197	464	98	455	189	454	2032	463	2005	464	10920	459	987
485	217	494	108	485	206	484	2184	493	2141	494	11827	489	1068
515	237	524	118	515	223	514	2335	523	2277	524	12720	519	1148
545	256	554	128	545	239	544	2484	553	2411	554	13589	549	1226
575	275	584	138	575	255	574	2630	583	2541	584	14433	579	1302
605	293	614	149	605	271	604	2773	613	2668	614	15268	609	1377
635	312	644	158	635	286	634	2911	643	2793	644	16078	639	1451
665	330	674	168	665	302	664	3043	673	2910	674	16872	669	1522
695	347	704	177	695	318	694	3170	703	3023	704	17666	699	1592
725	363	734	186	725	334	724	3293	733	3132	734	18461	729	1661
755	379	764	195	755	350	754	3414	763	3238	764	19245	759	1729
785	394	794	203	785	365	784	3531	793	3343	794	20011	789	1795
815	408	824	211	815	380	814	3646	823	3444	824	20750	819	1858
845	421	854	219	845	395	844	3759	853	3543	854	21459	849	1920
875	434	884	226	875	410	874	3869	883	3640	884	22148	879	1980
905	446	914	233	905	425	904	3978	913	3736	914	22818	909	2038
935	458	944	241	935	439	934	4085	943	3831	944	23456	939	2094
965	469	974	247	965	452	964	4191	973	3925	974	24068	969	2148
995	480	1004	254	995	464	994	4294	1003	4017	1004	24659	999	2201
1025	491	1034	260	1025	476	1024	4396	1033	4107	1034	25226	1029	2251
1055	501	1064	266	1055	488	1054	4498	1063	4197	1064	25773	1059	2301
1085	512	1094	272	1085	499	1084	4597	1093	4285	1094	26299	1089	2349
1115	521	1124	278	1115	509	1114	4695	1123	4371	1124	26807	1119	2396
1145	531	1154	284	1145	520	1144	4792	1153	4457	1154	27294	1149	2441
1175	540	1184	290	1175	530	1174	4889	1183	4542	1184	27765	1179	2485
1205	549	1214	295	1205	540	1204	4984	1213	4626	1214	28215	1209	2528
1235	558	1244	300	1235	550	1234	5077	1243	4709	1244	28642	1239	2569
1265	566	1274	306	1265	559	1264	5169	1273	4791	1274	29039	1269	2609
1295	575	1304	311	1295	568	1294	5260	1303	4871	1304	29414	1299	2647
1325	584	1334	316	1325	577	1324	5351	1333	4951	1334	29773	1329	2684
1355	591	1364	320	1355	585	1354	5442	1363	5030	1364	30108	1359	2719
1385	599	1394	325	1385	593	1384	5531	1393	5108	1394	30427	1389	2754
1415	607	1424	330	1415	601	1414	5620	1423	5187	1424	30729	1419	2788

Note 1: The time given for each sampling area is the average of the elapsed times for the three swatches tested per sampling area.

Note 2: The avg. time is the sum of the times given for each sampling area divided by the number of sampling areas.

Note 3: Weighted average  $M_f = 0.5(\text{Suit Matl } M_f) + 0.2(\text{Suit Seam } M_f) + 0.1(\text{Boot Matl } M_f) + 0.1(\text{Glove Matl } M_f) + 0.05(\text{Boot Seam } M_f) + 0.05(\text{Zipper/Matl Interface } M_f)$ .

## Appendix J

**Table J-2. Kappler Level B CSM Responder - Average GB Permeation**

Kappler Level B CSM Responder (42489)													
Time (min)	Suit Material	Time (min)	Suit Seam	Time (min)	Glove Material	Time (min)	Boot Material	Time (min)	Boot Seam	Time (min)	Zipper/Material Interface	Average Time (min)	Weighted Average M <sub>f</sub>
4	0	13	6	4	2	5	1	14	6	13	6	9	2
34	6	43	42	34	21	35	9	44	52	43	35	39	19
64	12	73	95	64	30	65	15	74	139	73	64	69	40
94	16	103	160	94	35	95	21	104	258	103	89	99	63
124	23	133	235	124	37	125	30	134	399	133	114	129	91
154	31	163	316	154	40	155	39	164	542	163	141	159	121
184	39	193	399	184	44	185	49	194	681	193	170	189	151
214	47	223	476	214	54	215	57	224	809	223	201	219	180
244	55	253	549	244	65	245	66	254	921	253	231	249	208
274	63	283	620	274	73	275	74	284	1021	283	263	279	234
304	71	313	688	304	82	305	82	314	1114	313	295	309	260
334	78	343	754	334	89	335	89	344	1200	343	328	339	284
364	85	373	817	364	97	365	95	374	1276	373	360	369	307
394	94	403	876	394	106	395	103	404	1345	403	394	399	330
424	101	433	934	424	115	425	110	434	1416	433	432	429	352
454	109	463	988	454	122	455	116	464	1486	463	471	459	374
484	116	493	1039	484	131	485	122	494	1552	493	511	489	394
514	123	523	1087	514	141	515	128	524	1611	523	553	519	414
544	131	553	1133	544	152	545	133	554	1666	553	597	549	434
574	138	583	1179	574	163	575	138	584	1721	583	643	579	453
604	145	613	1220	604	173	605	142	614	1770	613	690	609	471
634	152	643	1260	634	183	635	147	644	1817	643	737	639	488
664	158	673	1297	664	192	665	151	674	1863	673	780	669	505
694	166	703	1333	694	202	695	155	704	1908	703	819	699	522
724	172	733	1368	724	211	725	159	734	1948	733	853	729	537
754	179	763	1401	754	220	755	162	764	1986	763	884	759	552
784	185	793	1433	784	229	785	166	794	2027	793	912	789	566
814	193	823	1463	814	237	815	170	824	2065	823	939	819	580
844	199	853	1492	844	244	845	174	854	2099	853	965	849	593
874	206	883	1519	874	251	875	175	884	2115	883	990	879	605
904	213	913	1546	904	258	905	175			913	1014		
934	220	943	1571	934	264					943	1036		
964	226	973	1597	964	271					973	1059		
994	234	1003	1621	994	277					1003	1081		
1024	241	1033	1644	1024	283					1033	1103		
1054	247	1063	1667	1054	290					1063	1125		
1084	254	1093	1689	1084	296					1093	1147		
1114	261	1123	1710	1114	301					1123	1169		
1144	268	1153	1730	1144	308					1153	1193		
1174	275	1183	1749	1174	314					1183	1222		
1204	282	1213	1768	1204	322					1213	1253		
1234	289	1243	1786	1234	330					1243	1279		
1264	296	1273	1804	1264	336					1273	1299		
1294	302	1303	1821	1294	341					1303	1316		
1324	309	1333	1838	1324	346					1333	1333		
1354	316	1363	1853	1354	350					1363	1348		
1384	322	1393	1869	1384	353					1393	1362		
1414	329	1423	1884	1414	358					1423	1379		

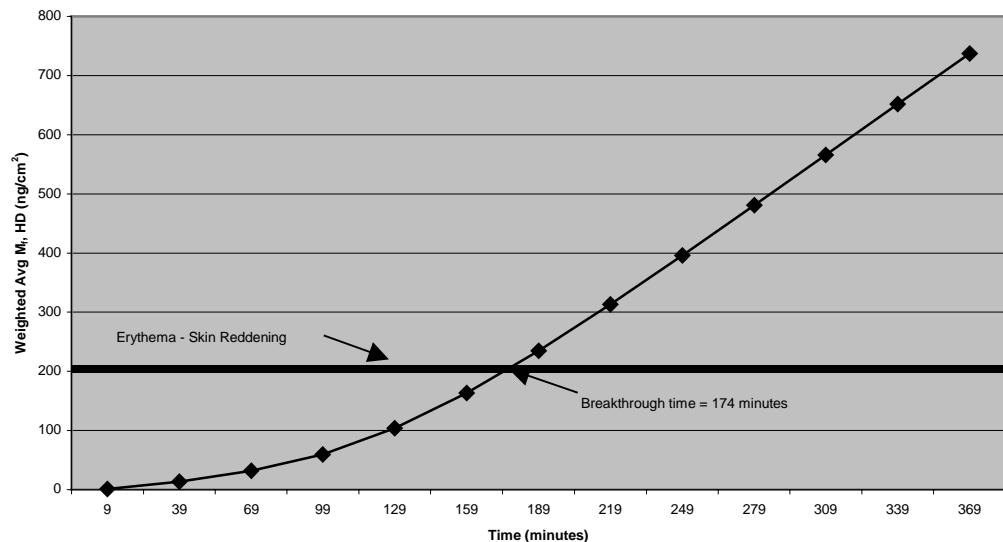
Note 1: The time given for each sampling area is the average of the elapsed times for the three swatches tested per sampling area.

Note 2: The avg. time is the sum of the times given for each sampling area divided by the number of sampling areas.

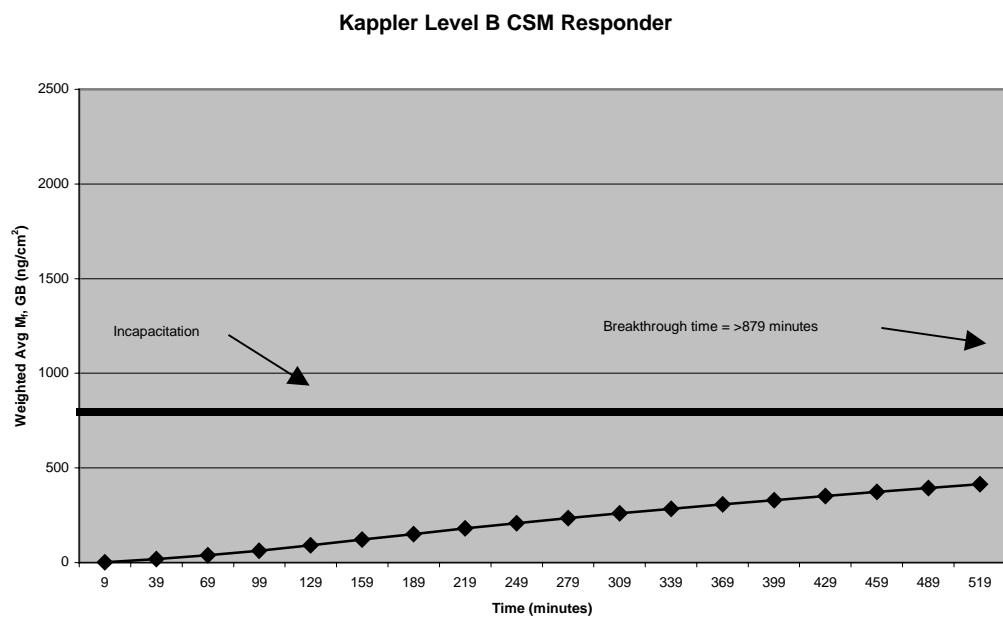
Note 3: Weighted average M<sub>f</sub> = 0.5(Suit Matl M<sub>f</sub>) + 0.2(Suit Seam M<sub>f</sub>) + 0.1(Boot Matl M<sub>f</sub>) + 0.1(Glove Matl M<sub>f</sub>) + 0.05(Boot Seam M<sub>f</sub>) + 0.05(Zipper/Matl Interface M<sub>f</sub>).

## Appendix J

### Kappler Level B CSM Responder



**Figure J-3: Kappler Level B CSM Responder - Weighted Average HD Permeation**



**Figure J-4: Kappler Level B CSM Responder - Weighted Average GB Permeation**

### Kappler Level B CSM Responder

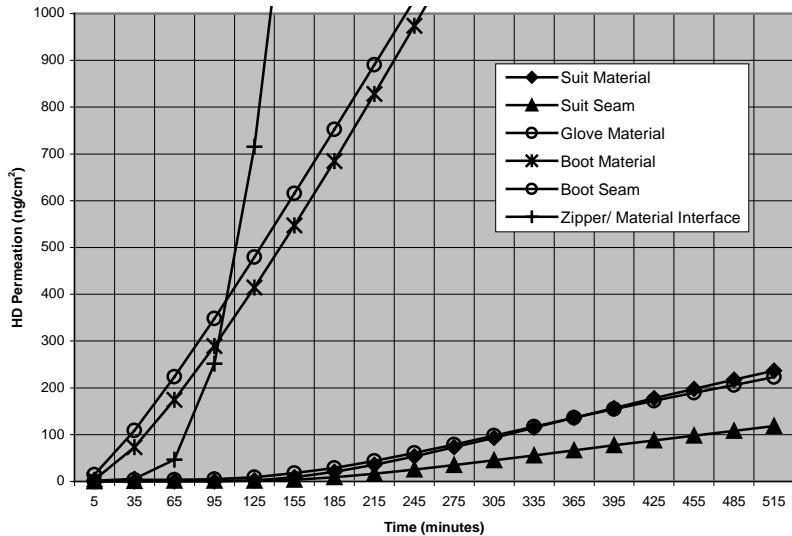


Figure J-5: Kappler Level B CSM Responder - HD Permeation by Sampling Area

### Kappler Level B CSM Responder

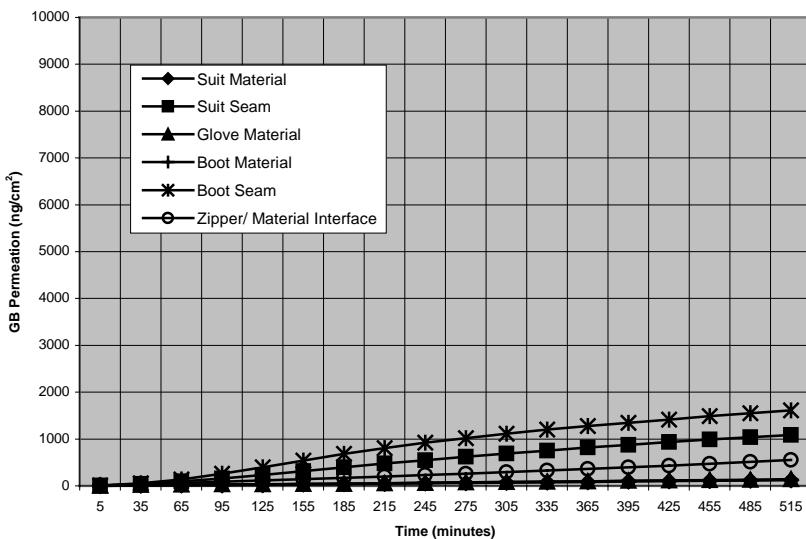


Figure J-6: Kappler Level B CSM Responder - GB Permeation by Sampling Area

**Table J-3: Kappler Level B CSM Responder - System Test (Aerosol Simulant) Results**

PF Range	Visor Region and Upper Arm, Combined					
	Pre-Operational Exercises			Operational Exercises		
	No. of Occasions in Range	Cumulative Rate, Percent	Cumulative Pass Rate, Percent	No. of Occasions in Range	Cumulative Rate, Percent	Cumulative Pass Rate, Percent
0	0	0	100	0	0	100
2	12	50	50	12	50	50
5	10	91	8	11	96	4
10	2	100	0	1	100	0
No. of Trials	24			24		

**Table J-4. Kappler Level B CSM Responder - Overall Test Results**

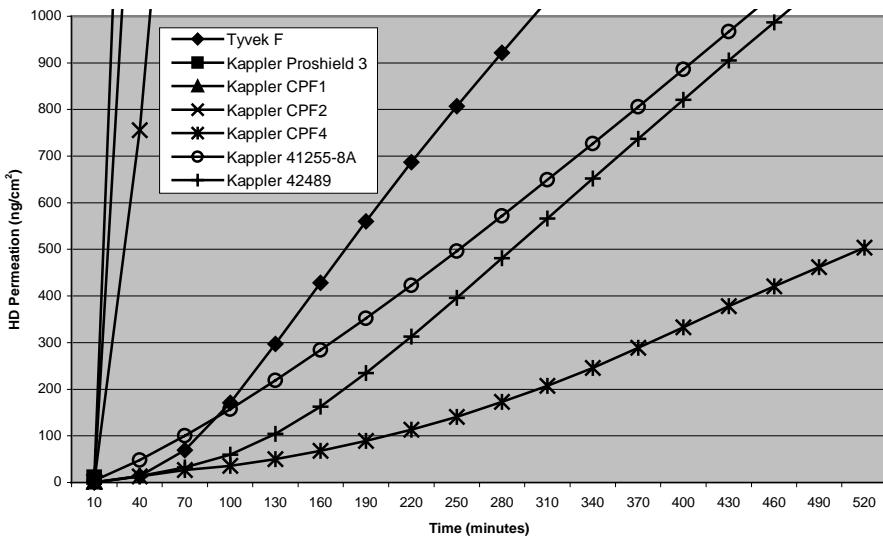
Breakthrough Time (minutes)		Aerosol PF Pass Rate at PF Equal to:			Exercise Phase
Incapacitation	Erythema	2	5	10	
GB	HD				
>879	174	50	8	0	Pre-Operational
		50	4	0	Operational

Blank

**APPENDIX K**

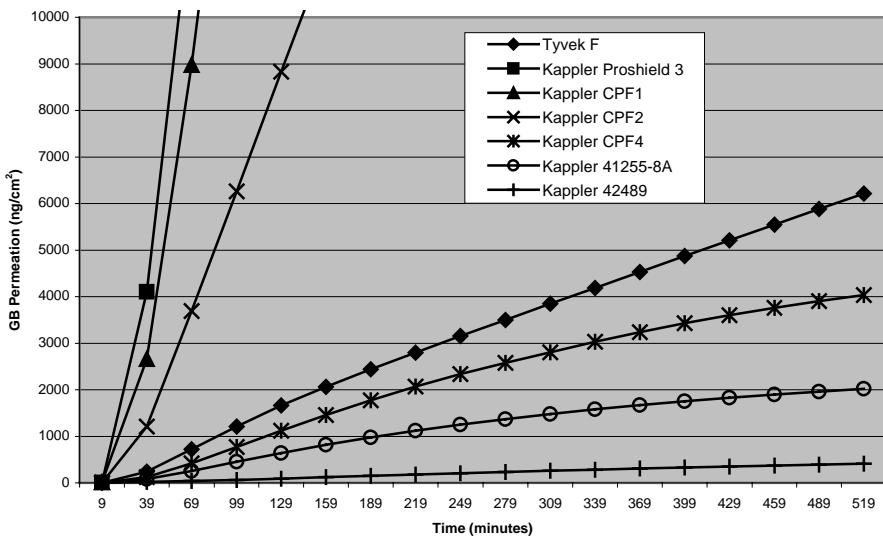
**OVERALL TEST RESULTS**

### Summary of HD Permeation Results



**Figure K-1: Weighted Average HD Permeation**

### Summary of GB Permeation Results



**Figure K-2: Weighted Average GB Permeation**

## Appendix K

**Table K-1. Summary of Overall Results for all Level B Suits**

Test Item	Breakthrough Time (minutes)		Aerosol PF Pass Rate at PF Equal to:			Exercise Phase
	Incapacitation	Erythema	2	5	10	
	GB	HD				
TFR4 CB Protective Coverall	76	107	58	0	0	Pre-Operational
			46	0	0	Operational
Kappler ProShield 3 Coverall	16	12	50	13	0	Pre-Operational
			50	0	0	Operational
Kappler CPF1 Coverall	19	14	50	0	0	Pre-Operational
			46	0	0	Operational
Kappler CPF2 Coverall	30	18	50	13	0	Pre-Operational
			50	0	0	Operational
Kappler CPF4 Coverall	102	303	50	0	0	Pre-Operational
			46	0	0	Operational
Kappler Responder (41255-8A)	156	120	42	0	0	Pre-Operational
			21	0	0	Operational
Kappler Level B CSM Responder (42489)	>879	174	50	8	0	Pre-Operational
			50	4	0	Operational

Appendix K